

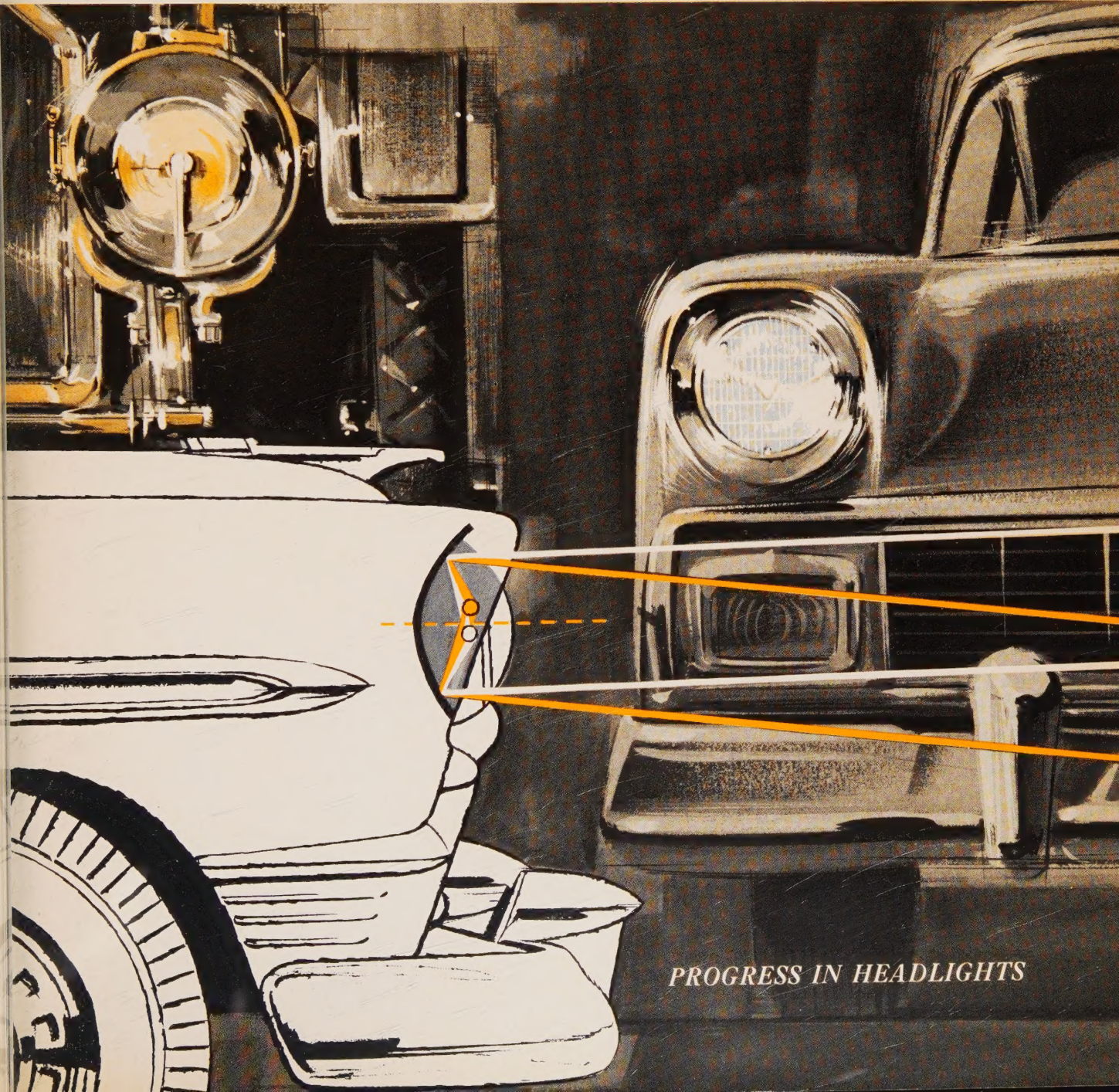
GENERAL MOTORS

Engineering

Volume 3 January-February 1956 Number 1

JOURNAL

for educators in the fields of engineering and allied sciences



PROGRESS IN HEADLIGHTS

On the Inquiring Mind*



IN MY OPINION there are four reasons for GM's success. These are, first, the dynamic growth of our country; second, the even more rapid growth of the automotive industry; third, our management structure and fourth, our approach to problems . . .

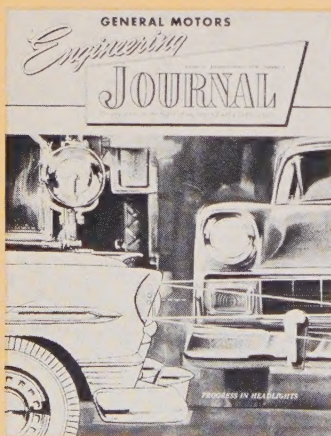
Our approach to problems is really an attitude of mind. It might be defined as bringing the research point of view to bear on all phases of the business. This involves, first, assembling all the facts; second, analysis of where the facts appear to point, and third, courage to follow the trail indicated even if it leads into unfamiliar and unexplored territory. This point of view is never satisfied with things as they are. It assumes that everything and anything—whether it be product, process, method, procedure, or social or human relations—can be improved.

I have tried to think of a single term to describe this attitude, and I think perhaps the closest is the *inquiring* mind . . .

H. H. Curtice

Harlow H. Curtice
President,
General Motors Corporation

*Excerpts from a statement by Harlow H. Curtice, December 2, 1955; copies of full statement available on request to the editor.



THE COVER

Progress in automotive headlighting is depicted in this issue's cover—another by artist Ernest W. Scanes portraying developments in transportation. Symbolizing this progress are versions of an early motor vehicle lamp and its 1956 successor which represents both a technical improvement and a styling advance. An enlarged sectional view of today's lamp demonstrates the principle of the parabolic reflector with light sources at the focus and above the

focus to change the direction of the light beam.

The modern lamp utilizes a more efficient reflector, long-life tungsten filaments, and a combination of flutes and prisms in the lens to control illumination, and three locating buttons on the lens to position a new aiming device—the result of continuous research and study of basic principles of optics and light to insure greater safety and pleasure for the automobile user.

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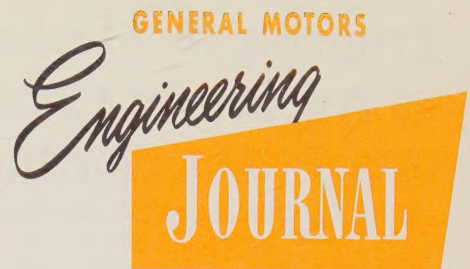
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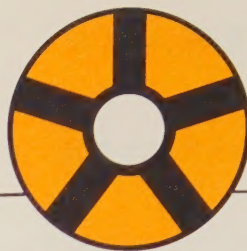
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Progressive Mechanization as Applied to Core Making in a Production Foundry



By CLIFFORD W. HOCKMAN
Cadillac Motor Car Division

Since the advent of the Industrial Revolution, the human effort connected with manufacturing operations has decreased steadily. Through the years machines have eased the work and drudgery of man and have changed the aspects of manufacturing. This progressive mechanization has influenced, in one way or another, every type of industry. In the foundry industry, where human muscles at one time played a major role in production, new innovations in the form of automatic machines have steadily improved working conditions, have eliminated unfavorable safety conditions, and have increased the efficiency of all operations pertaining to the production of castings. Core making, which was traditionally a hand operation, also has been affected by progressive mechanization; first in the form of single acting core blowers and then through multiple acting automatic core blowers. Before an automatic machine can be used, the need must exist and its overall effects on existing conditions thoroughly studied. At the Cadillac Motor Car Division's foundry, core making operations presented problems which, after thorough investigation, pointed to the introduction of automatic core blowers for their solution.

ENGINEERS continuously have been concerned with developing methods to minimize the human effort connected with foundry operations. The methods introduced have resulted in improved working conditions and in increased efficiency in the production of a great variety of castings.

The engineer's effort to alleviate the laborious and disagreeable phases of foundry work has taken place over a span of many years. Because of the peculiarities and complexity of the foundry industry, progressive mechanization has been a gradual process. The changes made, however, have affected every phase of overall foundry operation, including core making.

Core making is an important operation in a foundry. Castings requiring a cavity or recess must have some form of a core introduced into the mold. In a production foundry where many castings of complicated metal parts are made a great number of cores are required for each day's production.

The core making operation at the Cadillac Motor Car Division foundry recently presented problems which were the outgrowth of increased production schedules for that Division's own product and also of increased demands for castings produced for other General Motors Divisions and outside buyers. A study made pointed to the utilization of multiple acting automatic core blowers to

solve the problems. This is the story of how one phase of progressive mechanization improved existing conditions and provided facilities for maintaining a consistently high level of quality production.

A Need Arises for Progressive Mechanization

Cadillac Motor Car operates a gray iron foundry which pours an average of 450 tons of molten metal per 16-hr day from one cupola on an alternating cycle. The foundry's facilities include a Pattern Shop, four cupolas, three production molding lines, a jobbing floor, a Core Room, and a Casting Cleaning and Finishing Department capable of processing all castings produced. The foundry produces every cast-metal part used on Cadillac automobiles, such as cylinder blocks, cylinder heads, and intake and exhaust manifolds. In addition, the foundry produces castings for the Division's Cleveland, Ohio, Tank Plant and also casts transmission cases, retainers, and other miscellaneous parts for GM's Detroit Transmission Division. Lastly, a wide variety of experimental and small lot castings is made for other General Motors Divisions and outside buyers.

In all, there are over forty different kinds of production castings which range in shipping weight from 0.46 lb for a rocker-arm bracket to 235.33 lb for a cylinder block. Of the 40 various production castings, 27 use a total of 86

Engineers improved quality,
efficiency, and safety with
automatic machines

different cores which range in weight from 0.01 lb for a plug core to 80.30 lb for an unassembled crankcase core.

In the summer of 1952, the foundry's Core Room encountered difficulty in meeting increased production schedules. The Core Room, at that time, was equipped with conventional single acting and double acting, double roll-over, pneumatic core blowing machines. These machines utilized the medium of compressed air to blow a core sand mixture at high velocity into the cavity of a two-part (cope-and-drag) core box. The cavity had the shape of the desired core. In operation, the top of the core box was brought into a sealing contact with a flat blow plate attached to the machine's sand magazine. The blow plate had strategically placed holes of various diameters which directed and controlled the flow of core sand into the core box cavity. After a core was "blown," the core box was rotated, the cope separated from the drag, and the core removed or drawn. Single acting machines handled one core box at a time. Double acting machines had the provision for handling two similar core boxes to produce the same core—while one core box is in the blow position the other core box is in the draw position.

Space limitations within the area of the Core Room were such that the use of additional conventional-type core blowing machines to meet the production increase would be a difficult matter. Furthermore, the increase in production scheduled for 1953 indicated that the existing problems regarding core production would be intensified.

A study was made of the situation. Information was obtained concerning the development of a multiple acting

automatic core blower which represented, in general, a combination of several conventional-type blowers into one synchronized machine operating on a fixed mechanical cycle. Intensive examination was concentrated by Cadillac Motor Car's engineers on this machine and visits were made to plants where it was being used. Consideration was given to the effects the installation of an automatic core blower would have on production, on product quality, and on operational production and maintenance costs. The overall study showed that the automatic core blower had the potential for solving the problems existing in the Core Room.

The manufacturer's original design of the automatic core blower called for the use of five identical open- or dump-type core boxes and one blow plate, all inter-

locked with a five-station indexing turntable. (A dump-type core box produces a one-piece core which does not require a two-part, cope-and-drag core box.) At each station a specific operation pertaining to a core's production could be performed and the turntable automatically rotated the core box from station to station. This particular design, while embodying fully automatic operation, would produce only one type of core during an operational run as, for example, an exhaust manifold core; therefore, it did not possess the complete versatility required if the increased production schedules were to be met. Also, the space required to store the one type of core produced until needed was not available.

In view of this, Cadillac Motor Car's engineers, working in conjunction with

the manufacturer, set about modifying the original design to meet the Division's major specification which called for the automatic core blower to handle five core boxes—each of which would produce a different core during an operational run. This specification was achieved with cope and drag core boxes as well as with the open- or dump-type core box. All of the core boxes were fitted with individual blow plates (sub-blow plates) which were designed specifically to mask off the blow holes in the master blow plate which is attached to the sand magazine of the automatic core blower. The purpose of masking or blocking off the blow holes of the master blow plate was to direct the flow of sand into the core box cavity to produce a clean, solid blown core.

Fig. 1 shows a view of the first auto-

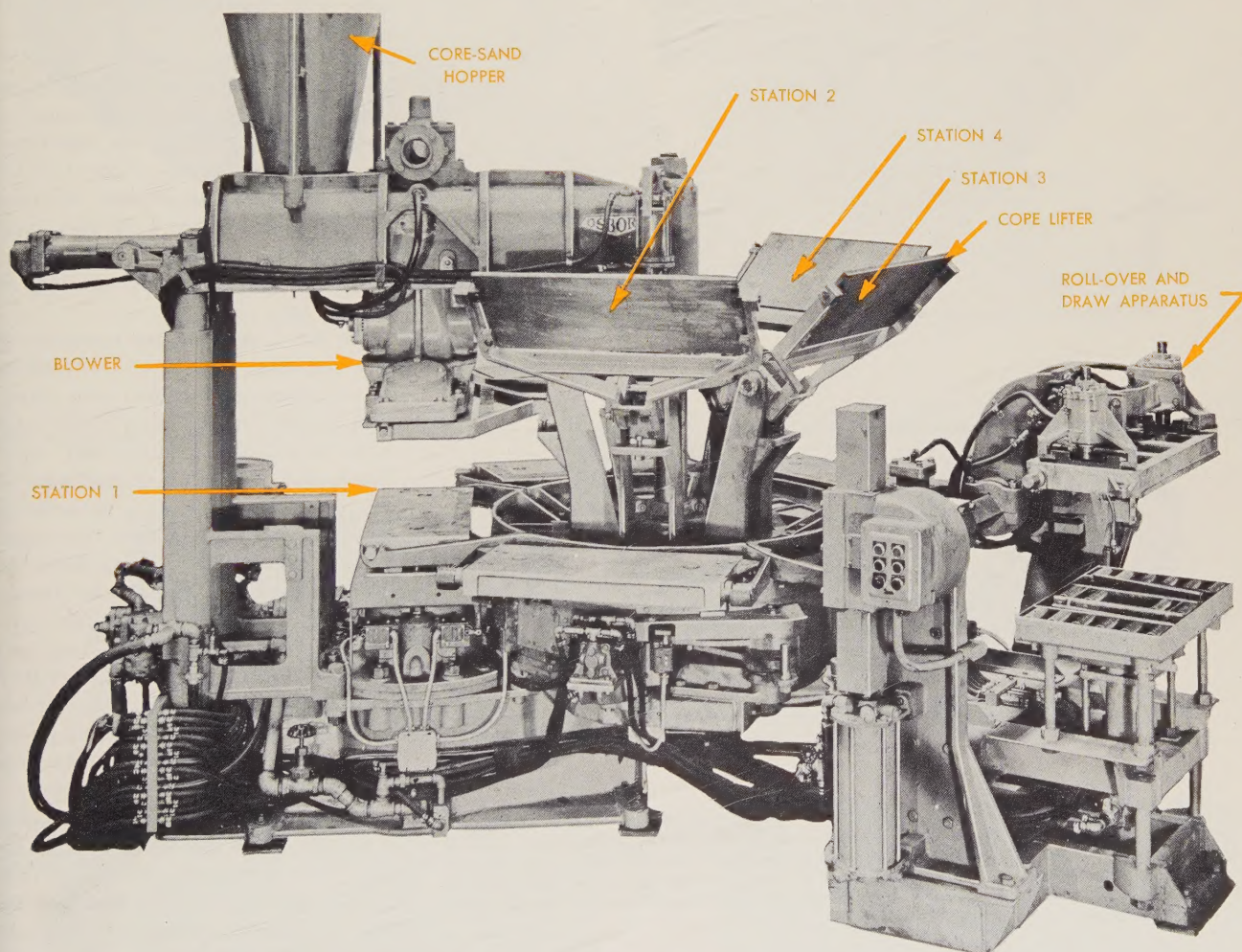
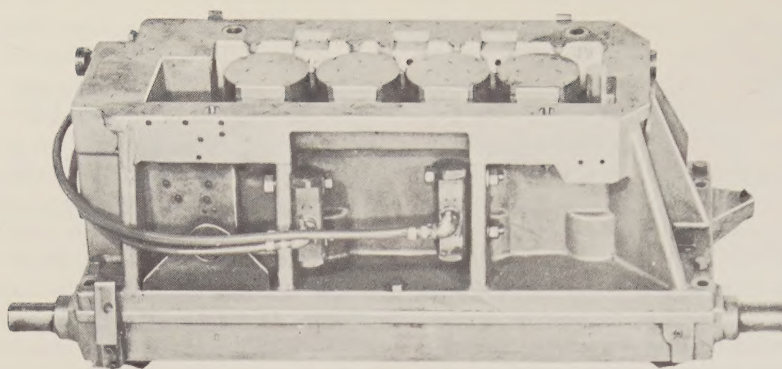
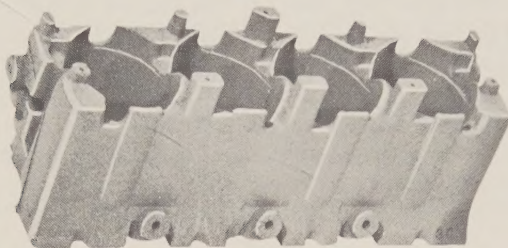


Fig. 1—The multiple acting, electro-pneumatic, five-station automatic core blower utilizes either open-type or conventional cope-and-drag core boxes (not shown) to produce five different cores during an operational run. At each station a specific operation relative to a core's production is performed. At station 1 the core is blown, at station 2 any required core dryers or core plates are positioned on the core, at station 3 the core box is revolved and the core

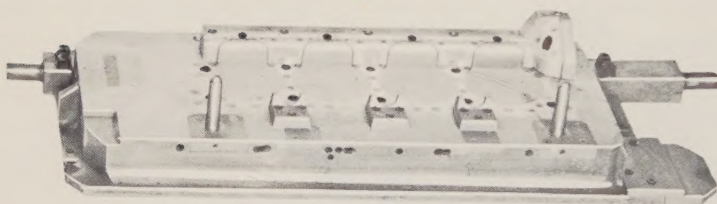
drawn, at station 4 the core box is blown clean by compressed air and a liquid parting agent applied, at station 5 (not shown) the upper and lower sections of a core box are brought together prior to the core blowing operation at station 1. Fig. 8 shows in more detail the specific operations performed at each of the five stations.



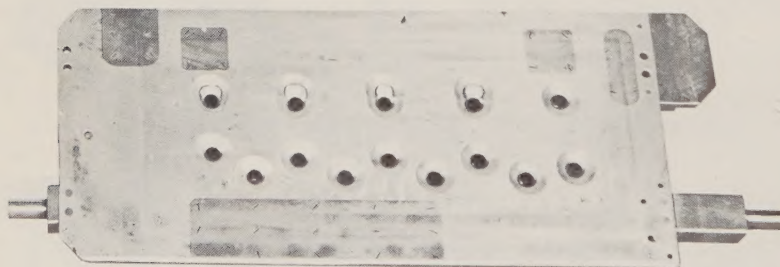
a



b



c



d

Fig. 2—The cavity of an open-type core box (a) has the shape of the desired core (b). This particular open-type core box produces a left-hand, cylinder block water-jacket core. Each open-type core box is fitted with a sub-blow plate (c) which controls and directs the flow of core sand into the cavity. The sub-blow plate, which is an integral part of the cope lifter, is brought into a sealing contact with the top of the core box prior to the blowing operation. The top of the sub-blow plate (d) has holes which register with holes in the master blow plate of the automatic core blower.

matic core blower—referred to as the No. 1 machine or blower—installed in the Cadillac Motor Car foundry. At present, there are two automatic core blowers in operation. The second auto-

matic core blower—referred to as the No. 2 machine or blower—is similar in operation to the No. 1 machine but produces different type cores and uses only conventional cope-and-drag core

boxes. These core boxes, however, also were designed specially by Cadillac Motor Car's engineers. Each individual cope section is fitted with a sub-blow plate which works in conjunction with the blower's master blow plate.

Fig. 2a shows a view of the open-type core box used to produce a left-hand cylinder block water-jacket core (Fig. 2b). This core box, as with all the open-type core boxes used on the No. 1 machine, is of one-piece design. Fig. 2c shows the bottom of the box's sub-blow plate which automatically is brought into a sealing contact with the core box immediately before the core is blown. Fig. 2d shows the sub-blow plate's top surface which is in contact with the master blow plate and the location of the holes through which the core sand mixture is blown into the core box cavity. Fig. 3a shows the open-type core box used to produce the cylinder block barrel core along with its respective sub-blow plate. Fig. 3b shows the cope-and-drag core box used to produce the bottom section of the cylinder head core assembly. With this type of core box, the sub-blow plate is attached to the cope half of the core box and the blow holes in the sub-blow plate are in complete alignment with the blow openings in the core box.

The No. 2 machine uses conventional cope-and-drag core boxes to produce intake and exhaust manifold cores, water-pump body cores, water-pump pipe center cores, and retainer-shaft cores. The *retainer shaft* is an integral part of the power drive unit of a transmission which transmits power from the engine to the propeller shaft. Fig. 4a shows the cope-and-drag core box used to produce the right-hand exhaust manifold core. Fig. 4b shows the cope-and-drag core box used to produce the retainer-shaft core. The cope section of each core box is fitted with an individual sub-blow plate which was designed specially to work with the machine's master blow plate.

The size, arrangement, and spacing of holes used to direct and control the flow of sand through the master blow plate and sub-blow plate and into the core box cavity presented an intriguing design problem. Each of the 10 sub-blow plates had to have a specific hole size and spacing to obtain the proper directional flow of the mixed sand into each particular core cavity. Each master blow plate, in turn, had to have holes of cor-

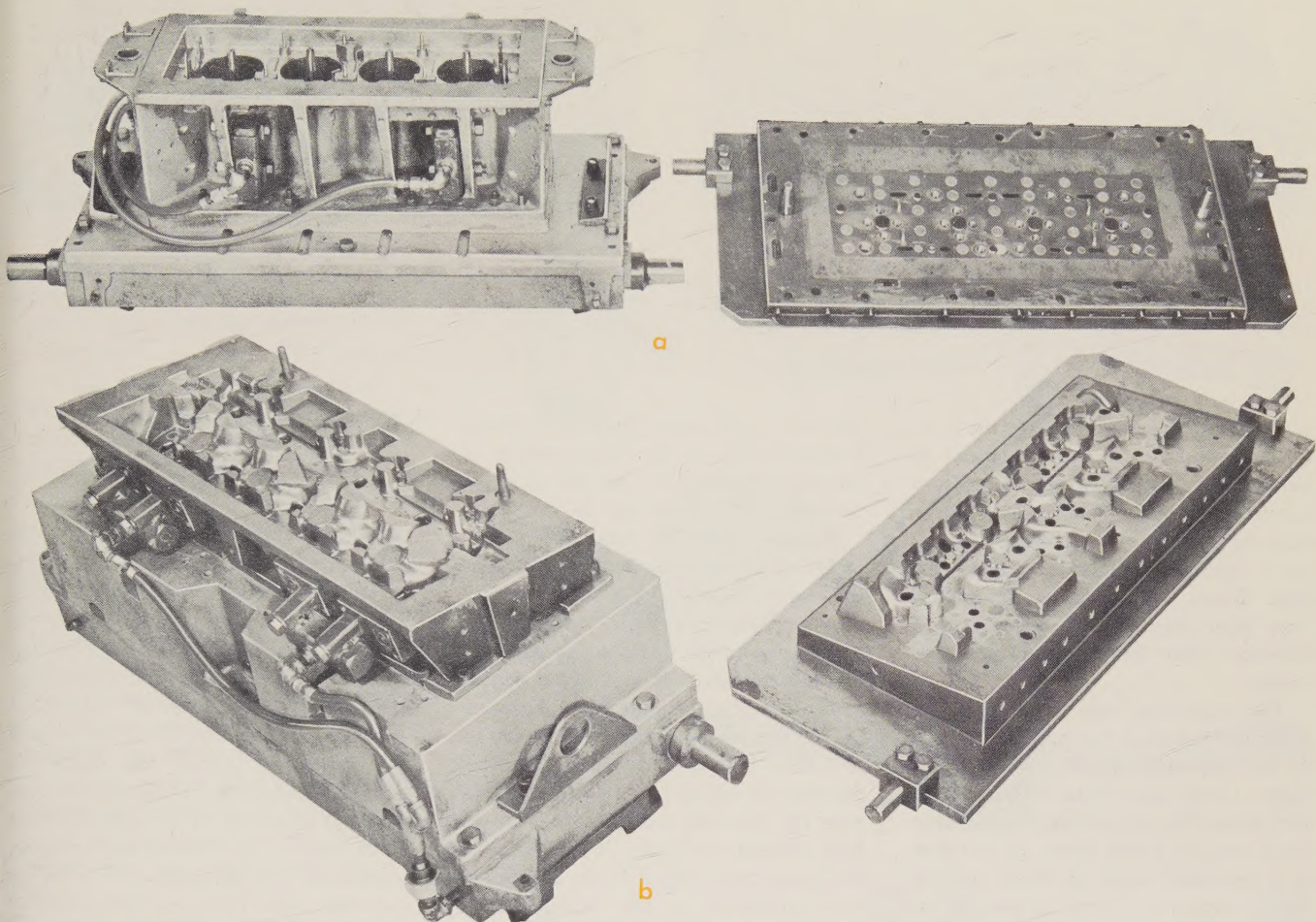


Fig. 3—The No. 1 automatic core blower uses both the open-type core box and the cope-and-drag type of core box. Two of the individual core boxes used

and their respective sub-blow plates are (a) cylinder block barrel open-type core box and (b) cylinder-head bottom-jacket cope-and-drag type core box.

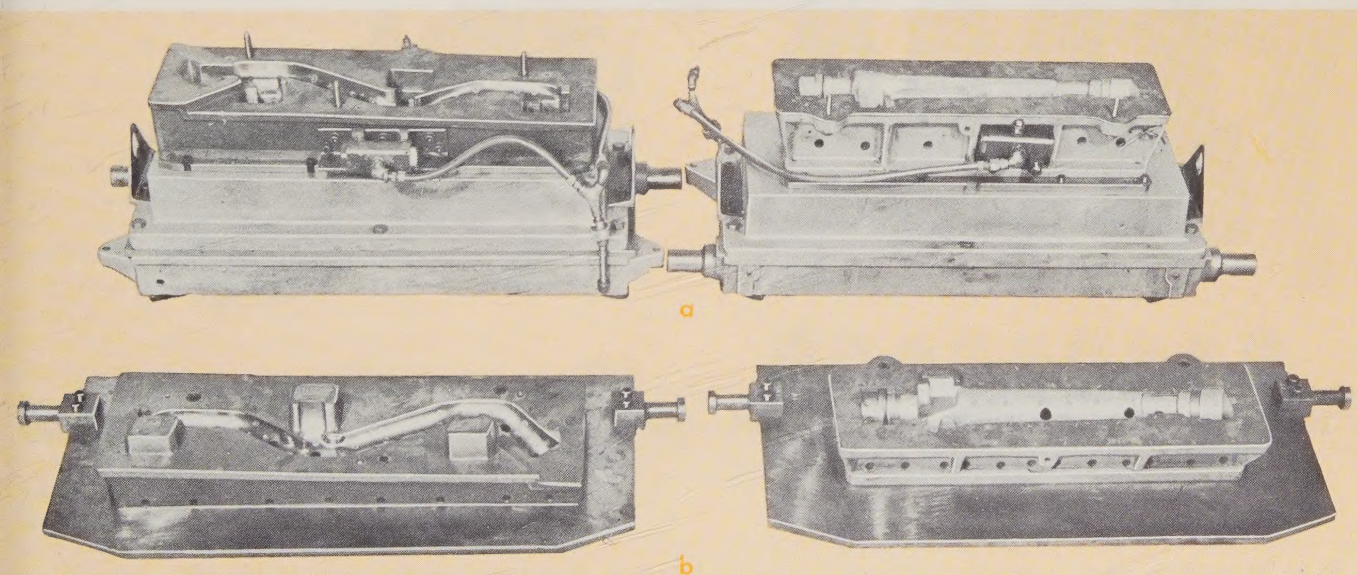


Fig. 4—The No. 2 automatic core blower uses conventional cope-and-drag core boxes to produce five different cores during an operational run. Two of the core boxes used are pictured with the cope section of each box which is

fitted with a sub-blow plate, shown below in each case. A right-hand exhaust-manifold core box is shown at the left and a retainer-shaft core box at the right.

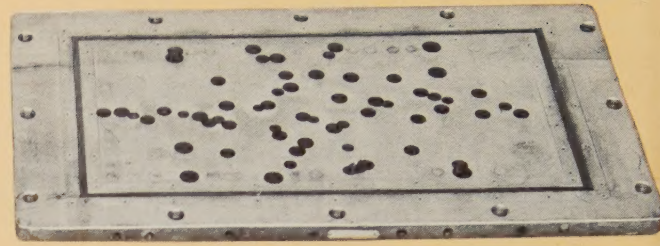
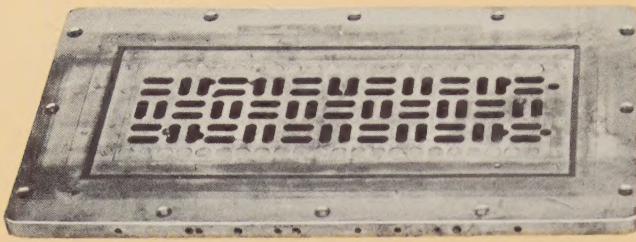


Fig. 5—Each master blow plate has a sufficient number of holes of correct size and spacing to register with the various holes of each individual sub-blow plate with which it is in contact. The master blow plate used on the No. 1

automatic core blower, as shown at the left-hand side, is identical with the master blow plate used on the No. 2 automatic core blower. Shown at the right is a sub-blow plate used for the open-type core boxes.

rect size and spacing to match the holes of the sub-blow plates with which it would be in contact. No definite rule was available as to the number and size of holes to use. Past experience and judgment were relied upon to achieve the final design. Fig. 5 shows the master blow plate used in conjunction with a sub-blow plate for the open-type core boxes.

The open-type core boxes produce irregularly shaped, flat-base cores (Fig. 6a and 6b) which do not require a core dryer. Cores made from cope-and-drag core boxes (Fig. 6c and 6d), on the other hand, require a core dryer. (A *core dryer* is a precision metal or plastic casting which supports a core to prevent its sagging or collapsing in the "green" or

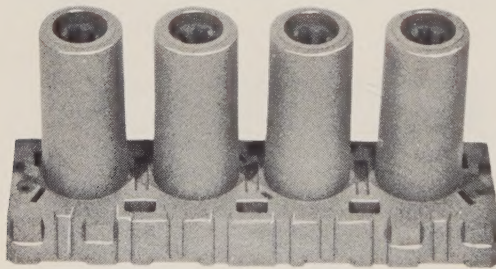
before-the-bake state. The dryer, having a shape similar to the upper portion of the core, is positioned over the core just before it is rolled over and drawn.)

Because of the flat base, only a core plate is required to provide support for the cores while being baked. (A *core plate* is a flat plate made of steel, iron, aluminum, magnesium, or pressed asbestos fiberboard. The length, width, and thickness of the plate are determined by the size and thickness of the core to be baked. The plate has holes of varying diameter at spaced intervals for the purpose of providing sufficient transfer of heat through the holes to the base of the green core.) Fig. 7 shows additional cores produced by the cope-and-drag core boxes used on the No. 2 machine

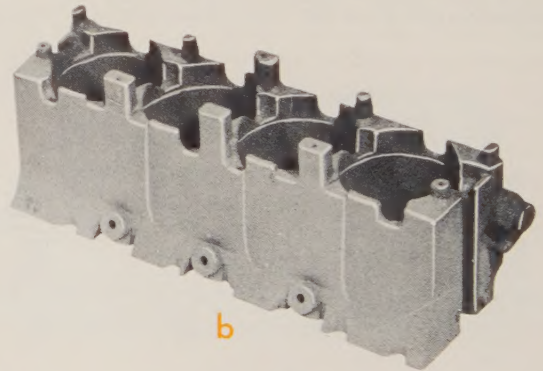
which require a core dryer.

Features and Operation of the Automatic Core Blower

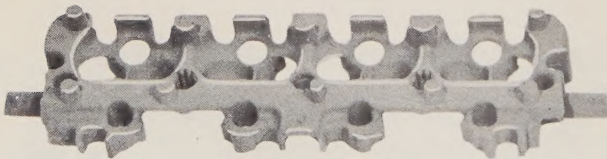
The multiple acting, electro-pneumatic, automatic core blower consists of a special core blowing mechanism and a roll-over and draw apparatus which is interlocked with a five-station indexing turntable. Nine solenoid valves, energized by 11 electrically activated cams, control the supply of compressed air required to operate the machine's various mechanisms. The automatic core blower is protected by 11 limit switches which control 15 different core making operations. The indexing cycle is set by a variable speed drive and the timing of operating cams. A modified Geneva



a



b



c



d

Fig. 6—The cores produced from the open-type core boxes have flat bases and require a core plate to provide support during the baking process. Five different cores are produced by the No. 1 automatic core blower which uses both the open-type and the cope-and-drag type of core box. The cores produced, in addition to the left-hand cylinder block jacket core shown in Fig. 2, are (a)

cylinder block barrel core, (b) right-hand cylinder block jacket core, (c) cylinder-head bottom jacket core, and (d) cylinder-head top jacket core. The cylinder head water-jacket cores are produced by the cope-and-drag type of core box.

movement controls the acceleration and deceleration of the indexing turntable and permits either clockwise or counterclockwise rotation by the proper adjustment of the compressed air supply lines to an indexing cylinder. Additional control buttons allow the indexing turntable, blower, or roll-over and draw apparatus to operate independently and facilitate maintenance. The design of the automatic core blower is such that more circuits can be wired into the system to handle any additional core making operations which might be required.

The automatic core blower can blow 421 cores per hour but experience has shown that the most efficient operation results when the blower operates on a 10-sec cycle and blows 360 cores per hour. Both the No. 1 and No. 2 machines are set at this cycle speed and the indexing turntable of both machines is set to rotate in a counterclockwise direction.

The operation of the automatic core blower is governed by the five-station indexing turntable. Fig. 8 shows the relative position of each station and the operations performed on the No. 1 machine as the turntable rotates from station to station. The operational procedure is the same for both machines with the exception that the No. 2 machine does not require the use of a power vent.

Cores are vented for the purpose of providing a means for the release of gas when the mold is poured. Not all cores, however, require vents. The cores produced by the No. 2 machine are in this category. Because venting is peculiar to each type of core, the automatic core blower had no provision for this operation. As a result, Cadillac Motor Car's engineers designed and installed a high-pressure, air-operated power-vent mechanism which places a clean and clear opening into the most strategic location of cores requiring vents produced on the No. 1 machine. The power vent is activated by a limit switch and has an adjustable timing control so as to permit the use of any combination of cores in any sequence on the five-station indexing turntable.

The open-type core boxes and their respective sub-blow plates, which are an integral part of the automatic blower's cope-lifter mechanism, and also both sections of the conventional cope-and-drag core boxes are mounted on platens which, in turn, are supported on cradle arms at each of the five stations. This

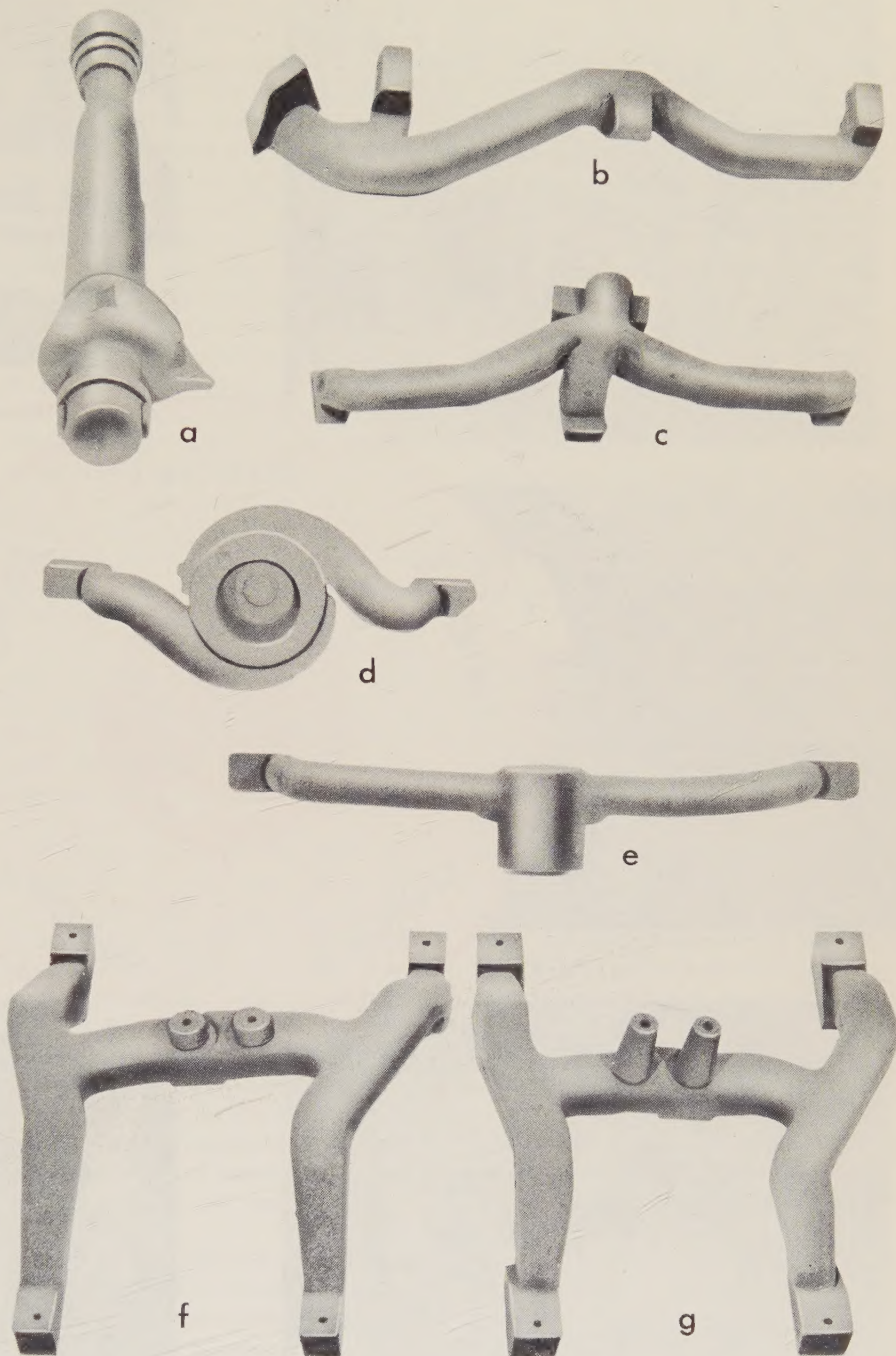


Fig. 7—The cores produced by the conventional cope-and-drag core boxes on the No. 2 automatic core blower require the use of a core dryer to provide support during the baking process. Representative of the cores produced by the No. 2 automatic core blower are (a) retainer-shaft core, (b) right-hand exhaust manifold core, (c) left-hand exhaust manifold core, (d) water-pump body core, (e) water-pump pipe center core, (f) left-hand intake manifold core, and (g) right-hand intake manifold core.

arrangement eliminates bolting and unbolting and allows a complete core box to be changed in an average of 4 min as compared to 15 min to 20 min on the conventional single acting and double

acting core blowers. Also, when one core box must be removed for any necessary repairs or maintenance it can be quickly lifted out of the cradle arms while a limit switch is set so that the

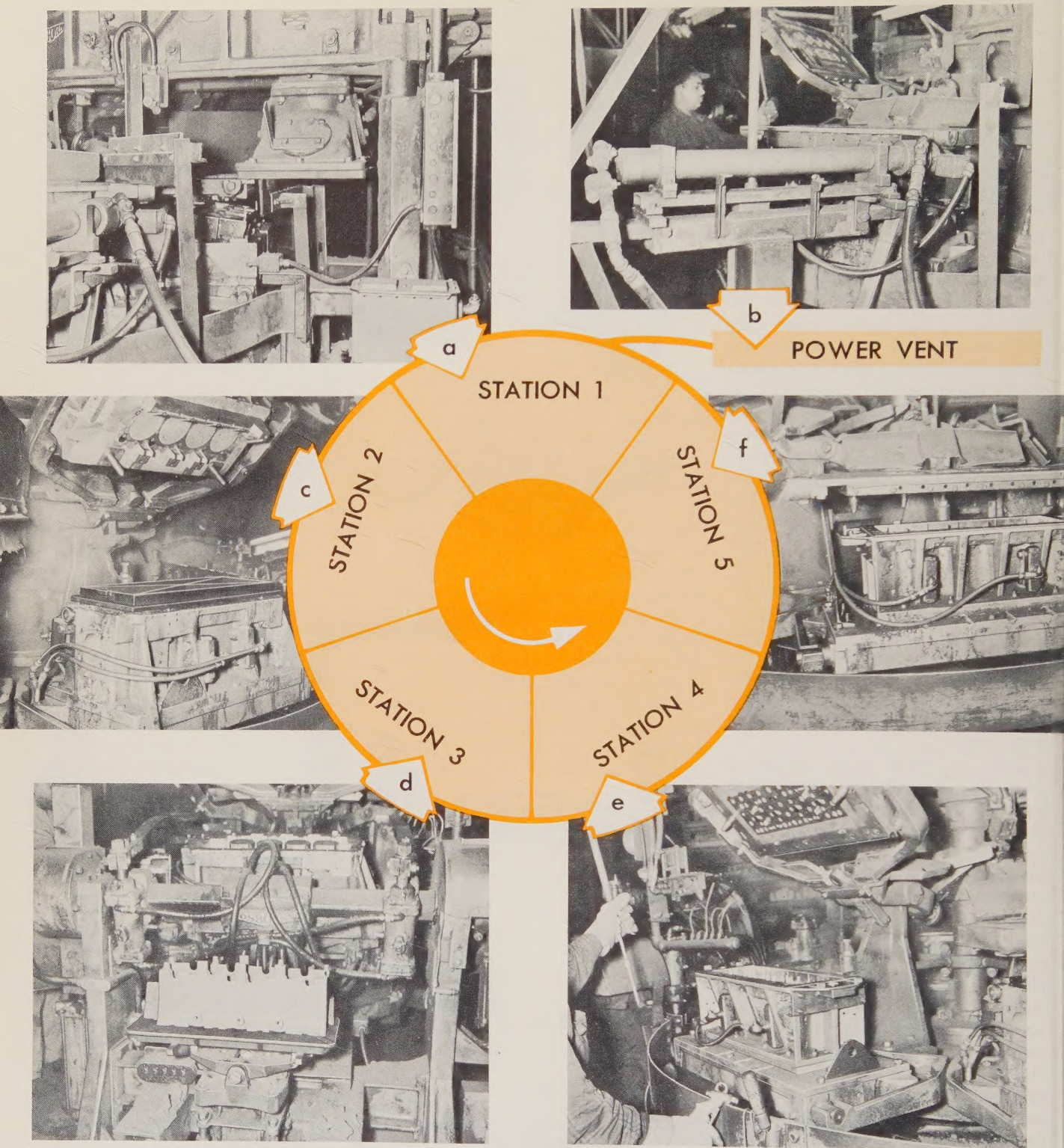


Fig. 8—A five-station, counterclockwise, indexing turntable governs the operation of the automatic core blower. The sequence of operations for the No. 1 machine is as follows: at station 1 a sand magazine moves outward from the indexing turntable and receives sand from an overhead sand hopper. At the same time, an empty core box is indexed into the "blow" position. The filled sand magazine then moves inward until it reaches a point directly above the core box. The core box is then raised, clamped to the sand magazine, and the core blown (a). The power vent (b) goes into operation and places a vent opening in the core. The core box is then lowered and indexed to station 2. At this station, the cope lifter raises the sub-blow plate and a core plate is placed on the exposed core (c). The core box, with the cope lifter remaining

in the "up" position until lowered again at station 5, is indexed to station 3 where roll-over clamps grasp the top of the core plate. The core box is then revolved 180° and the core drawn (d). While the roll-over mechanism revolves back to its original position for another core box, an operator places the drawn core on the core-oven conveyor. The empty core box is then indexed to station 4 where it is first blown clean by compressed air. A liquid parting or sand-release agent is then sprayed into the core cavity. The operator uses a compressed air hose held in his left hand to blow the core box clean and uses his right hand to direct the liquid parting spray (e). Next, the core box is indexed to station 5 where the cope lifter lowers the sub-blow plate into position (f). Finally, the core box is indexed to station 1 and the cycle repeated.

machine continues running the other jobs and skips the empty station at the blower.

The open-type core box size of 15 in. by 36 in. and a draw of 10 in. eliminated the possibility of making relatively large cores by the automatic core blowers. (The large size cores continue to be made by heavy-duty conventional core blowers.) The cores finally chosen to be made by the two automatic core blowers were critical cores from the standpoint of required quality and quantity which could most readily be made from the same core sand mixture.

In order to locate the two machines effectively it was necessary to place one on each side of an existing horizontal core-oven conveyor. This resulted in having stations 2 and 3 of each machine adjacent to the conveyor and enables easy removal of cores for placement on the conveyor.

The core blowing air pressure for each automatic core blower is 135 psi and the air volume for each core blowing action is approximately twenty-six cubic feet. This allows the production of a core which is dense and clean cut—a core which does not require reinforcing wires or rods normally used to provide maximum strength for handling after baking and to withstand the pressure of molten metal when the mold is poured.

Post-Installation Additions

After the automatic core blowers had been in operation for a period of time and experience was gained as to their operational characteristics, Cadillac Motor Car's engineers began to make additions to the original equipment for the purpose of improving as much as possible the machines' operating efficiency and also to alleviate unnecessary maintenance and down time.

Bent or broken power-vent rods represented a major cause of down time and maintenance on the No. 1 machine when it was first put into operation. To relieve this situation, an improvement was made in the original design of the power vent. A funnel-shaped guide was substituted for the original bell-shaped guide and a telescopic cylinder was substituted for the original single acting cylinder. These substitutions made possible the use of a shorter vent rod and resulted in a more accurate vent stroke which reduces the number of bent and broken vent rods.

On the No. 2 machine, an automatic core-box spray was installed at station 4 which results in allowing the operator more time in which to handle the cores for placement on the core-oven conveyor. (The *core-box spray*, or sand-release agent, is a kerosene-base liquid mixed with a lard oil which cleans a core box of sand adherence and eliminates stickiness caused by core-oil deposit on the box's vertical core-cavity surfaces. The spray provides easy and clean release of a green core from the core cavity at the time of draw.) The automatic core-box spray was not installed on the No. 1 machine because a hand-operated spray is more effective for the purpose required on the deep draw, open-type core box such as that used to produce the cylinder block water-jacket core.

Rubber wipe-off grids which clean the sub-blow and master blow plates of loose sand were installed around the core blowing station of each machine. This addition results in the sub-blow plate and master blow plate being brushed clean by the movement of the indexing turntable and sand magazine before and after each blow and improves the overall blowing operation.

A safety feature, in the form of a braking device, was made an integral part of the cope lifter. The braking device insures that the cope lifter is held secure while in the "up" position and protects the operator's hands from injury which might result from the possibility of the cope lifter suddenly lowering without warning. Another safety device installed prevents the indexing turntable from reversing its counterclockwise direction of rotation and damaging the cope-handler cylinder or endangering the operators.

To eliminate roll-over clamp maintenance and core breakage, steel blocks were added to the lighter weight core boxes in order to equalize the weight of all core boxes and to enable proper and fixed adjustment of the roll-over and clamps. Also, better control and smoother operation of the roll-over were obtained by using a power source to motivate the down-stroke of the draw mechanism in place of the original source of gravity motivation.

Measures taken to eliminate down time included replacement of 5-gal spray tanks by tanks of 20-gal capacity which removed the necessity of refilling during a 16-hr production run. Also, light

panels were wired to the limit switches to provide an immediate picture of which switches were not functioning. This allows an easy diagnosis of limit switch trouble.

One of the most important post-installation additions was an automatic lubricating system which keeps all moving parts continually oiled. Oil is injected into the bearings in such a manner as to prevent the entry of dirt and sand.

Another addition involved a change in the cope-handler cam rollers. The original rollers were mounted to a center shaft by means of lock washers which had a tendency to jar loose. These rollers were replaced by rollers of different design which are held fast to the center shaft in such a manner as to eliminate the need for lock washers and bearings. A final addition involved changing the indexing slide's bronze wear plates to hardened and ground steel wear plates.

Summary

The installation of the two automatic core blowers has greatly increased the productive capacity and actual production of cores in the Cadillac Motor Car foundry. The automatic core blower represents the combination of several conventional blowers into one synchronized unit, the elimination of laborious and disagreeable manual operations, and the substitution of a mechanically fixed cycle for manual control of a machine's frequency of operation.

The automatic core blowers have improved core quality and have facilitated standardization of the core making process at Cadillac Motor Car. The cores made by the automatic core blowers are harder, denser, and cleaner than they were when made by the conventional single acting and double acting core blowers. This has resulted in cores being less susceptible to breakage while being transported in the green to the core oven. Also, smoother finishes in the casting cavities and recesses have resulted.

The additions and auxiliary installations designed by Cadillac Motor Car's engineers have eliminated unnecessary maintenance and down time and the need for the conventional core blowers, outside of the heavy-duty blowers used for the large size cores, as stand-by equipment. This, in turn, has relieved congested space conditions, improved working conditions, and supplied all the cores required to meet the production schedule.

A Look at the Career of Alfred P. Sloan, Jr., Chairman of the Board, General Motors



Engineering students looking ahead to their careers often examine the lives of successful individuals to discover guides which they can apply to their own plans for a future in engineering. The past fifty years have seen many prominent industrial leaders whose careers merit attention of this kind. One such man—an engineering graduate himself—is Alfred P. Sloan, Jr., chairman of the Board of Directors, and former chief executive officer of General Motors. Mr. Sloan's conspicuous contributions to the national scene—technical, economic, and social—are recognized in many ways. Among recent examples of this recognition was the award to him of the Hoover Medal in 1954. One of the highest awards in the engineering profession, the medal honors an individual engineer who has distinguished himself in service to the public. Young engineers, then, well might direct certain questions to Mr. Sloan and study his answers as well as other pertinent facts drawn from his experience as an engineer and an executive.

Q: In your opinion, Mr. Sloan, what is the best equipment with which the young engineer can begin his career?

A: "The fundamental tool with which the engineer works is basic knowledge. He must have a constant supply of basic knowledge, provided by fundamental research, to support the processes of applied research, advanced engineering, and production. I believe history will demonstrate that far too much of the basic knowledge upon which we, in this country, have relied in the past, and which the engineer has capitalized so effectively, has been associated with foreign sources. We have been better at adapting than we have at creating. Somehow, we have failed to fire adequately the imagination of our own brilliant young minds with an urge to devote their lives to the cause of fundamental science. Whatever we, as engineers or as managers or whatever we may be, can contribute in our own way to encourage the expansion of basic research, assuredly to that degree will we be expanding the tools with which the engineer works. Of course, it is not always realistic in dealing with the practical problems of life to adhere strictly to the fundamentals. Life is a series of compromises. But you will find that you can never make the best decision unless you first establish the fundamental facts."

Mr. Sloan was one of the first automotive leaders equipped with a formal technical education. He attended Polytechnic Institute of Brooklyn and, later, Massachusetts Institute of Technology. By studying through summers, he completed the four-year course in three, earning the Bachelor of Science degree in electrical engineering in 1895.

Q: From your long experience with a large corporation, is there any one basic ground rule which you feel would benefit the young engineer just starting out?

A: "Perseverance. When any man has formed an association in the early stages of a developing business—one that is producing something of benefit to the community or performing some useful service—his road into the future, I believe, is clearly defined. He should help make it a success. Stick to it. I have really had only one job as far as I am concerned. When I began my career, I started out in a small manufacturing company in Newark. It was struggling along on a new thing and through the force of circumstances, the way those things happen, I've been with that outfit as it has moved from place to place ever since."

Mr. Sloan became general manager of the Hyatt Roller Bearing Com-

How can engineers' technical contributions result in maximum social significance?

pany in 1899 and actively directed the company for over 17 years (Fig. 1); during this period, the business which began at a gross of less than \$2,000 a month passed the \$10,000,000 a year mark. In 1916 this Company became part of the United Motors Corporation which was made up of several manufacturers of automotive accessories. At the same time, Mr. Sloan joined the new group as president. United Motors and Mr. Sloan later became affiliated with General Motors where Mr. Sloan progressed to the position of chief executive officer. He served in this capacity from 1923 until 1946, nearly 23 years, spanning the crucial depression years when many other large business enterprises tottered and fell, and the more recent war years when the organization was devoted completely to war work.

Q: In a large organization such as General Motors how do you establish a working climate which is conducive for individuals in the lower strata of management to develop themselves so they can take the place of those higher up?

A: "General Motors has recognized the importance of preparing for the future in the management phase of its business. Determination of policy and its effective administration in an enterprise of the magnitude and scope of General Motors require talent of the highest order. What such talent may create in terms of more job opportunities, better product values, and additional profits is most important.

"The scheme of organization of General Motors is designed to establish a pattern of self-development to bring out the ability, resourcefulness, and imagination of the individual, not only at the top but at all levels of authority. By far the most productive approach is the placing of responsibility. That is what develops ability, resourcefulness, and leadership as nothing else can."

In his organization of General Motors, Mr. Sloan's plan of management divided it into as many units as were feasible, placing in charge of each the most capable executive that could be found. He developed a co-ordinating system so that each operating element—or GM Division—might support and strengthen each other section. In this way, he not only co-ordinated all the units in a common interest but, especially important, developed ability and initiative through the placing of responsibility and the encouragement of ambition. By giving the individual an opportunity to exercise his talents, he not only promoted their interests but those of the business as well.

Q: *In what way has the engineer contributed toward improved management techniques in industry?*

A: "The original concept of the province of the engineer was in the narrow area of what might be called applied research, that is, his basic professional activity. But with the evolution of our processes of mass production it was not long before it was recognized that the engineer's point of view was of vast importance to these processes. It was recognized that he could make an immense contribution by increasing the efficiency of the processes of production, in product engineering, and in the organization of production itself. Thus, the engineer, by the sheer force of his effectiveness and by demonstrating his capacity for leadership in production, tended to move out of the area of his strictly professional capacity and to take on the additional responsibilities of management and direction.

"When I was graduated from M.I.T. at the turn of the century, I was graduated as an electrical engineer. My classmates all had technical qualifications. Moreover, few, if any, had any ambition to enter into the broader phases of our economic life, such as management and



Fig. 1—(Right to left) Mr. Sloan, Harry Carroll, advertising manager of Hyatt Roller Bearing Company, and Henry Ewald, founder of Campbell-Ewald Company, holding a conference at Hyatt Roller Bearing in 1911. The Campbell-Ewald Company handled that Company's first advertising account.

similar responsibilities in our society. Out of a graduating class of approximately one hundred and fifty, less than half a dozen moved out of the strictly professional area in selecting their vocation in life. Today, the situation has changed radically. Many of our corporations are now headed by engineers in their capacity as chief executives. At one time recently, five of our greatest industrial enterprises simultaneously had engineers serving them in that capacity. I was told recently that the top industrial management of well over one-half of our 150 largest corporate enterprises is engineering-trained."

When Mr. Sloan became president of General Motors in 1923, the Corporation was a group of properties without any definite pattern. He grouped together those operations with similar interests (Fig. 2)—for example, the car manufacturing Divisions—and placed over each a group executive; these executives reported to him directly and the Division heads reported to their separate group executives. He then developed a general staff which was established on a functional foundation—engineering, distribution, personnel, legal, financial affairs, and so on. Each of these functions was then headed by a vice president for the purpose of assembling those duties which could be performed more effectively by one activity in the interests of all, and co-ordinating various activities of the individual operating groups. These vice presidents also reported directly to him.

Q: *Industry today seems to be bending every effort toward increasing its engineering talent. To what do you attribute this trend?*

A: "The post-war age is in every sense a research era. In any case, whatever the nature of the evolution or revolution of science may be, we shall need an ever-growing supply not only of trained professional engineers to deal with these problems but also trained engineering leadership to translate these scientific advances into the life of our technological age. Let me say, with the deepest of convictions, that there never has been a time in my many years of service to American industry when the future offered so much in the way of economic progress as now. We are on the eve of tremendous advances. The most imaginative of any of you cannot realize the ceiling of the possibilities; in fact, there need never be a ceiling if we continue our search for fundamental knowledge (Fig. 3). The measure of our accomplishments will be determined by our scientific progress, by its effective capitalization in the arts, by the climate of national economic policy created by government, and through the instrumentality of the American system of competitive enterprise motivated by the freedoms of the people."

At the time Mr. Sloan began his career, technical industry was just beginning. It was felt that progress was at a standstill, hampered as it was by the aftereffects of the early depressions. Yet, since that time his career has seen the inception of the radio, airplane, automobile, household refrigerator, and more recently

ORGANIZATION CHART GENERAL MOTORS CORPORATION

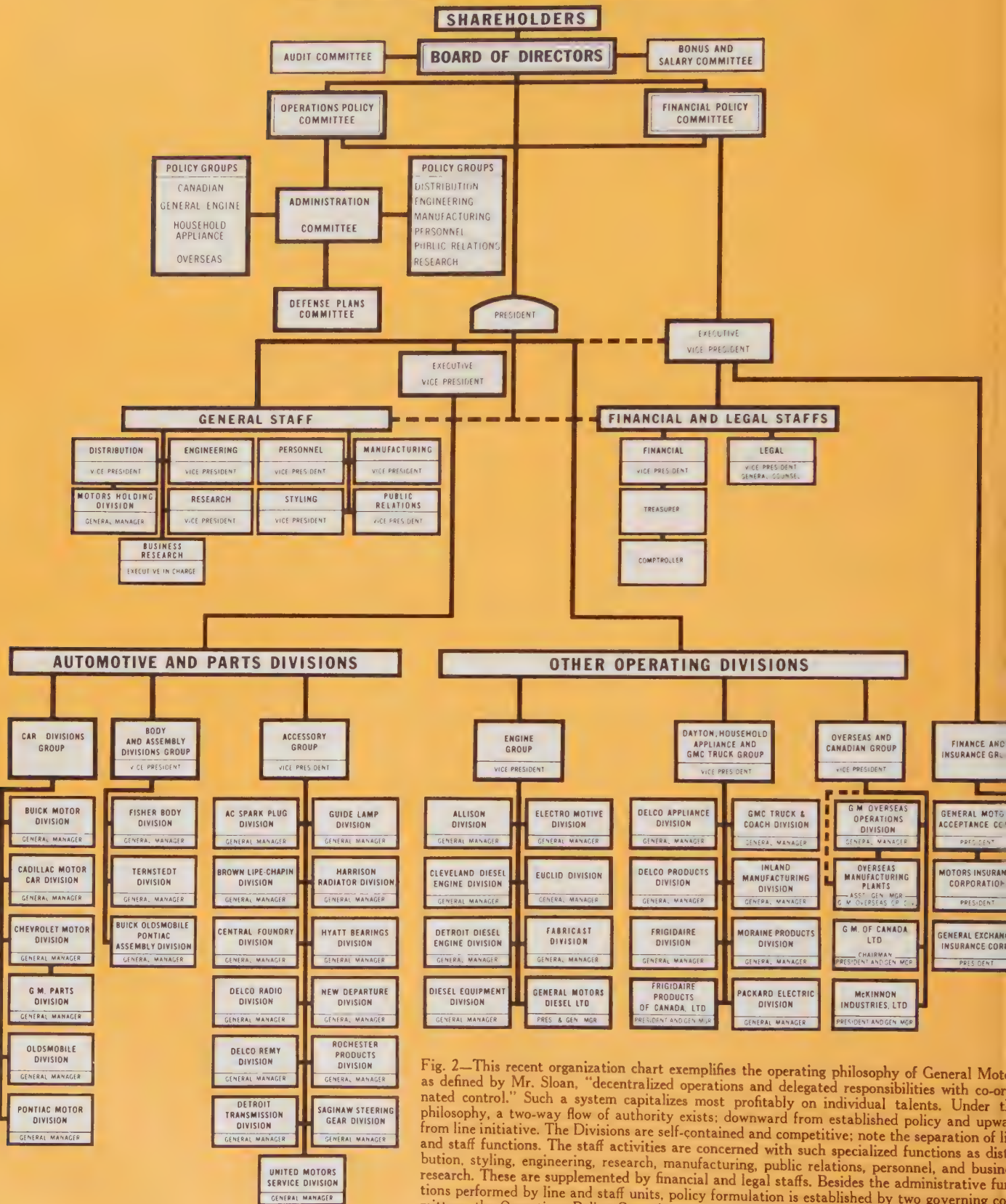


Fig. 2—This recent organization chart exemplifies the operating philosophy of General Motors as defined by Mr. Sloan, "decentralized operations and delegated responsibilities with coordinated control." Such a system capitalizes most profitably on individual talents. Under this philosophy, a two-way flow of authority exists; downward from established policy and upward from line initiative. The Divisions are self-contained and competitive; note the separation of line and staff functions. The staff activities are concerned with such specialized functions as distribution, styling, engineering, research, manufacturing, public relations, personnel, and business research. These are supplemented by financial and legal staffs. Besides the administrative functions performed by line and staff units, policy formulation is established by two governing committees, the Operations Policy Committee and the Financial Policy Committee. In addition, Administration Committee, which reports to the Operations Policy Committee, submits recommendations regarding manufacturing and selling activities.

the advancement of wonder drugs and atomic energy.

Q: *Mr. Sloan, would you comment on industry's responsibilities beyond those of developing, manufacturing, and distributing products economically?*

A: "Industrial management realizes today, as never before, that however competent it may be, it can no longer confine itself directly to the production of goods and services. It must accept responsibility for the impact of its decisions, at the policy level, upon society as a whole since these decisions affect the economic progress of the community and its stability. In other words, it must accept its share of responsibility for human progress and make its decisions in terms of industrial statesmanship. Hence, it is logical that the engineer in industry has a part in exercising this expanded responsibility, and he should recognize, as indeed he has, that there is more in business than business itself."

Mr. Sloan's direction of General Motors spanned many critical periods which tried the nation's economic patience. On February 14, 1933, for example, all financial institutions in Michigan were closed on order of the governor of that state. General Motors, with the Reconstruction Finance Corporation and on request of government authorities, set up a new bank in Detroit with a capital of \$25,000,000—one-half of which was supplied by General Motors. The objective at that time was to perform a service to the community of which his organization was, of course, an important part but a relatively small proportion of the total.

Q: *Would you present your personal philosophy regarding the responsibility of engineers toward mankind?*

A: "I believe that in our society, which owes so much to the engineer, the public—although aware of the significance of the engineer's professional activities—does not recognize fully and takes too much for granted his non-professional relations to society, his community service, his national leadership, in both an economic and social sense. As the engineer has moved into this area of broader responsibility in our society, the traditional attitude of the public toward him has been in a sense paradoxical. Almost

every schoolboy knows that our contemporary civilization is basically a technological culture. Our wealth, production, and standard of living are primarily the product of the engineer. It is only recently that he has entered broadly into the area of directing and managing the civilization to which he has contributed so much.

"Human progress has been actuated by scientific knowledge and the approach of the engineer. Yet the material values of human progress have far outdistanced the advancement of human behavior. Human nature too often is dominated by weaknesses. One of the major problems of the future—a real challenge to our civilization—is to bring human behavior more in line with human progress. We must create leadership and develop values in the social sphere which will measure up to our scientific and technological accomplishments and the material progress they have given our civilization."

One of the ways in which the engineer's broader role in society has been recognized in recent years has been through the awarding of the Hoover Medal which honors the public service of men who have gone outside of their strictly professional work to interest themselves in civic and humanitarian affairs. Originated in 1929, the first award of the medal was made in 1930 to Herbert Hoover. Mr. Sloan was given this award in October 1954 (Fig. 4). The award was made in recognition of his contribution to the American economy, his encouragement of engineering research in educational institutions, and his sponsorship in the field of medical research.

Q: *In your capacity as developer and leader of a successful industrial organization, what do you consider has been your greatest reward?*

A: "The accomplishment itself. The greatest thrill that life can offer is to overcome the obstacles that impede progress and develop something useful. It is as great a satisfaction to be devoted to such a cause as it is to be devoted to any other altruistic interest and ambition. Even more satisfying is the knowledge that the accomplishment is contributing toward advancing the community's social and economic status.

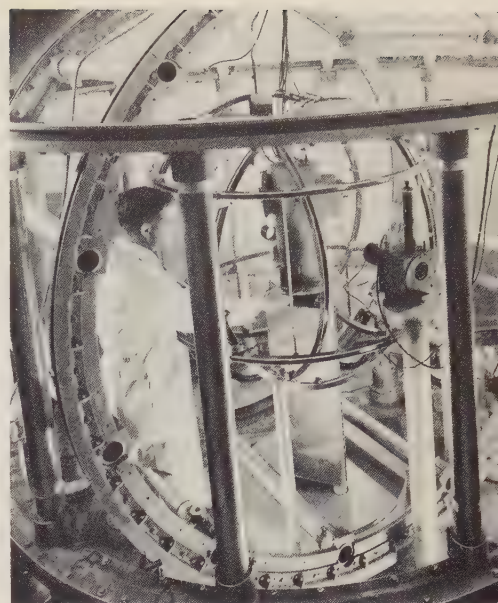


Fig. 3—In the normal repetitive framework of engineering, basic science is not always a necessity. Yet, wherever engineering improvement or fresh discoveries are taking place, a firm understanding of the basic rules of science frequently saves the engineering profession much time, energy, and expense. In addition, each new scientific contribution stemming from basic research often affects laws common to all engineering compartments. Representative of the fundamental scientific studies taking place in the General Motors Research Staff are those conducted by G. G. Scott on magnetic behavior. Within this compendium of Helmholtz coils which serves to neutralize the earth's magnetic field, acutely sensitive measurements are taken, in an evacuated chamber, of magnetic phenomena. There are only two other such precise magnetic measurements being performed today. Other recent studies in this field have involved exploration of magnetic domains and magnetic intensity of various alloys. Among the evocative industrial benefits inherent in magnetics are the development of permanent magnets, an explanation of the formation of grain structure, the development of better magnets for use in electric power generation, and clarification of the behavior of electrical machinery.

"An essential component in the capitalistic system is the motive of profit but it is far from being the sole force which motivates the individual in contributing to the greatest accomplishments of life. Beyond a certain materialistic point, soon reached, the dominant urge is for still greater success, recognition of the ability to accomplish, and an overall satisfaction of achievement. No material gains could possibly compensate for the anxieties, responsibilities, and sacrificing of one's own life for that of the cause. In helping to promote human progress, the individual achieves the highest standards of citizenship.

"In retirement as well, he may recognize that he has a debt to pay to society



Fig. 4—Professional recognition comes to engineers through many means and instruments. Engineers' social significance also receives comparative recognition through honors such as the Hoover Medal. Here Dr. Scott Turner, president of the American Institute of Consulting Engineers, is presenting the award to Mr. Sloan to honor his social contributions to mankind.

for the benefits he has enjoyed; that he has a responsibility to contribute his talent, his productivity, and his increased leisure in the discharge of that obligation."

Mr. Sloan established the Sloan Foundation which has made numerous grants for scientific education and research, much of it in the industrial management field. In 1953 the Foundation initiated a program to supply 200 four-year scholarships, valued up to \$2,000 annually, to 11 educational institutions to be awarded to students showing marked promise in engineering, science, and other subjects. That same year, 1953, Mr. Sloan and four other business leaders organized the Council for Financial Aid to Education. Supported in part by a grant from the Sloan Foundation, the Council announced that its purpose was to help colleges and universities obtain increased financial support from private enterprise. Then, in May 1955, the Foundation established a \$5,000,000 fund, the principal and interest of which are devoted to promoting basic research in the physical sciences. In addition, the Sloan Foundation has granted funds to help promote highway safety in communities throughout the nation. Mr. Sloan also is co-sponsor of the Sloan-Kettering Institute for Cancer Research, and is chairman of its Board of Trustees.

Q: What do you consider has been your outstanding or, let us say, most significant contribution to the industrial scene over the past half-century?

A: "Taking my own activities in life, I wouldn't say that I had distinguished myself particularly in a commercial way. My contribution to progress and to the business in which I spent my life is more in the way of engineering technique, improvement of our products, new devices, and the management phases and the engineering phases of business more than the direct commercial or selling phases."

Mr. Sloan's engineering background enabled him to apply scientific techniques to the operations of Hyatt Roller Bearing Company. As a result, the reliability and precision of its products made Hyatt Roller Bearing important in the infant automobile industry. Later, Mr. Sloan repeated the same technical pattern in his operation of the General Motors organization. Under his guidance, the basic units grew in productive efficiency and today reach into almost every corner of the free world. The fundamental policies which govern General Motors are attributed largely to Mr. Sloan's influence. The organizational pattern which he formed in those first years still serves as its guiding principle. Today, the soundness of the leadership which

he imparted is verified by the scope of GM's activities. The automobile dealer organization comprises more than 18,000 retail car and truck merchants in the U. S. who employ well over 200,000 sales and service personnel; the number of people on GM payrolls numbers more than 500,000 employees in the U. S., and over 21,000 prime suppliers furnish components which make up the final product.

Q: What would you say is the future of the engineer in industry?

A: "First of all, we need the engineering point of view, now, more than ever, and in the future, we will need it vastly more so than now. In the organization and direction of large-scale enterprises, economic or social, we need the respect that the engineer has for basic facts. We need his analytical frame of mind. We need his imagination. We need his contact with the interpretation and control of physical forces. Such is the type of discipline, as I see it, that is sure to contribute to a maximum degree of order in our complicated economy and promote the best and most efficient use of our national resources, both human and material."

"Early in 1954, General Motors announced a forward expansion program of capital expenditures calling for an outlay of about one billion dollars in 1954 and 1955. By the end of 1954 it was necessary to increase the total program to 1½ billion dollars. In June 1955 a new 500 million dollar program of capital expenditures was announced. Substantially, all of these expenditures will be completed by the end of 1956. In all, when this program has been completed General Motors will have expended in the United States and Canada four billion dollars for capital investment since the end of World War II. (This is in addition to very substantial expenditures for special tools during this period.) We are entering an age of unlimited research opportunities. Who among you has the imagination to forecast the peace-time future of nuclear energy in terms of higher living standards, better health, and the promotion of human progress in other ways. What the industrialists of the past 50 years have done is a mere beginning, with the area of greatest opportunity still beyond the horizon, and this will always be so as long as the frontiers of scientific knowledge continue to expand."

Alfred P. Sloan, Jr.

MR. SLOAN was born May 23, 1875, at New Haven, Connecticut, in a family background of learning and culture but in no sense of wealth. His father, Alfred Pritchard Sloan, Sr., was from an old upstate New York family. His father's father had been a schoolmaster. His mother was Katharine Mead, daughter of a Methodist minister. Mr. Sloan, Sr., was a tea and coffee importer and distributor.

The eldest of five children, Alfred, Jr., grew up in Brooklyn, bent on training as an engineer even though the profession then was not regarded generally as an important occupation.

He expedited his college entrance with special instruction at Polytechnic Institute of Brooklyn. Because he was too young to enter Columbia University, his first choice, he entered Massachusetts Institute of Technology in the fall of 1892. Through year-around study, he completed a four-year course in three and was graduated in 1895 as a Bachelor of Science in electrical engineering at the age of 20.

The next problem was to find a job. After considerable discouragement, Mr. Sloan located a position as draftsman with the Hyatt Roller Bearing Company, Newark, New Jersey—a company later to become a Division of General Motors.

Antifriction bearings at the time were a novelty so far as the mechanical arts were concerned, and Hyatt Roller Bearing was having a struggle as a pioneer bearing producer; there was no developed market.

It finally appeared as if the business would have to be liquidated when Mr. Sloan convinced his father and an associate that they should finance a six-month further trial to the extent of \$5,000. Young Alfred Sloan was to have direction and control of the business. He was named general manager of the company in 1899. The company made \$12,000 profit in the first six months which demonstrated that success was possible.

In his 17 years of direction of Hyatt Roller Bearing, the company's business



passed the \$10,000,000 a year mark. These years gave Mr. Sloan a diversified schooling in the method of making and selling automobiles, including design, engineering, production, sales, advertising, and executive direction.

In 1916 he was approached by W. C. Durant, then president of General Motors, with an eye toward joining a combination of accessory companies including Hyatt Roller Bearing.

With Mr. Sloan as president, the group was formed under the name United Motors Corporation, embracing Hyatt Roller Bearing; Dayton Engineering Laboratories Co., Dayton, Ohio; Remy Electric Co., Anderson, Indiana; New Departure Manufacturing Co., Bristol, Connecticut; Harrison Radiator Corporation, Lockport, New York; Jaxon Steel Products Co., Jackson, Michigan; Klaxon Co., Bloomfield, New Jersey, and several others.

In 1918 United Motors became a part of General Motors Corporation, Mr. Sloan being named a GM director and vice president in charge of accessory operations, and a member of the Executive Committee.

In November 1920, Mr. Durant retired as GM president and was succeeded by Pierre S. du Pont, then chairman of the Board. An executive post of vice president in charge of operations was created and Mr. Sloan was designated to assume that responsibility. In 1922 he was appointed to the Finance Committee.

Mr. du Pont, who had taken the GM presidency only at the earnest solicitation of many and at a time of emergency in the history of the Corporation, retired the post on May 10, 1923, remaining as Board chairman. Mr. Sloan was elected president.

Mr. Sloan served as GM president for 14 years, until May 3, 1937. In every one of these years, even 1932 when the automotive industry lost 75 per cent of its 1929 volume, GM made a profit and paid dividends to shareholders, both common and preferred.

Mr. Sloan was elected GM Board chairman in May 1937, relinquishing the presidency but continuing as chief executive officer with responsibility over all operations. After 1945 he continued as chairman but, having reached the age of retirement for active service to the Corporation, he passed on his responsibility of 23 years as chief executive officer to C. E. Wilson, president.

In addition to serving as Board chairman, Mr. Sloan continued as a member of the Financial Policy Committee, one of the Corporation's two top governing committees, and as chairman of the Bonus and Salary Committee. Prior to June 1946, he had been chairman of the Policy Committee, formerly the Corporation's top governing group, and until the end of World War II, chairman of the Administration Committee.

In 1947 a Doctor of Laws degree was conferred upon Mr. Sloan by Princeton University, in 1948 he was given a Doctor of Science degree by Duke University, and in 1950 he received an honorary degree of Doctor of Commercial Science from New York University.

The National Institute of Social Sciences, of which Mr. Sloan is a member, awarded him a gold medal on May 18, 1949 for "distinguished service to humanity." The Hundred Year Association of New York awarded him its 1951 gold medal for outstanding services to New York City.

He also has been honored by the National Highway Users Conference of which he was chairman for 15 years until 1948, and the Automobile Old Timers of which he is a life director and former honorary president.

Mr. Sloan is a life member of the Academy of Political Science, and a member of the Council on Foreign Relations, the Society of Automotive Engineers, and the New York Academy of Sciences. He is past president of the Economic Club of New York, a member of the lay board of the New York Academy of Medicine, a life member of the Massachusetts Institute of Technology Corporation, and a member of the Metropolitan Union, and University Clubs.

Applying Engineering Mechanics: Find the External Support Reactions of an Allison Turbo-Prop Engine

By HAROLD E. HELMS
Allison Division

One of the many problems encountered when designing a turbo-prop aircraft engine is the determination of external support reactions acting at each of the engine's three mounting points. The reactions must be determined accurately because the engine's structural design is completely dependent upon their magnitude. Various flight conditions create loads which require reaction at either two or three of the mounting points. Reactions acting in the vertical and the fore-and-aft directions may be determined by using the three basic equations of static equilibrium. Reactions acting in the side direction, however, make the engine a statically indeterminate structure and a more detailed analysis is required for their determination. The approach used is to determine the side reactions according to the spring rates of the engine, mounts, and airframe. A complete analysis based on the equations of static equilibrium and spring rates results in seven basic equations which completely define external support reactions for any possible combination of flight loading conditions.

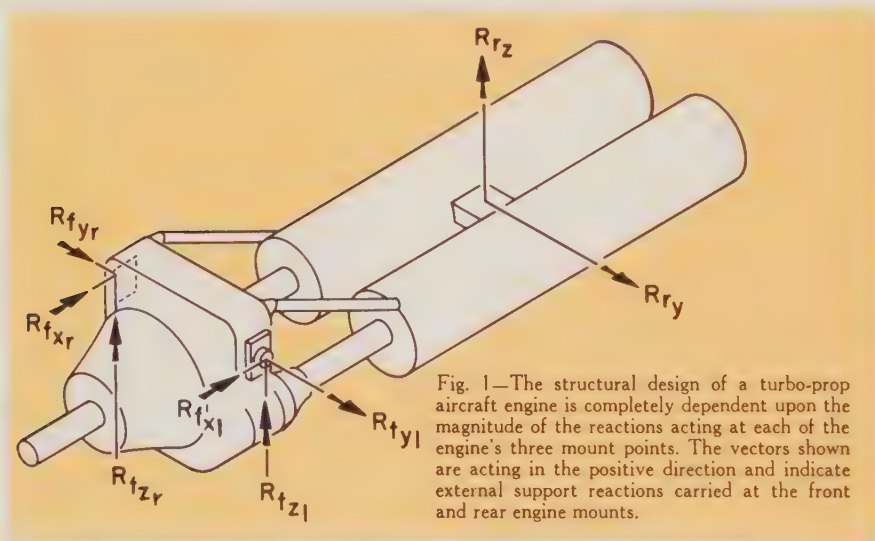


Fig. 1—The structural design of a turbo-prop aircraft engine is completely dependent upon the magnitude of the reactions acting at each of the engine's three mount points. The vectors shown are acting in the positive direction and indicate external support reactions carried at the front and rear engine mounts.

DETERMINING loads to be imposed on the engine structure is one of the problems of the turbo-prop aircraft engine designer at Allison Division. Three sources of information are available for determining the maximum loadings that will be encountered. These sources are government specifications covering loadings in flight maneuvers likely to be present in the general type of airframe for which the engine is intended, airframe manufacturers' specifications that call out loadings to which a specific airframe will be subjected, and engine performance specifications that state engine operating conditions which cause loads to act on the engine structure. After con-

sulting these sources, the engineer must convert these general specifications into specific loadings and then design the engine structure to carry these loads satisfactorily while holding weight to an absolute minimum.

A turbo-prop aircraft engine is mounted in a structural airframe with rubber, Fabreeka, or some other type of shock and vibration resistant material. These materials serve to isolate engine and propeller vibrations from the airframe. They also help to distribute load in given proportions by the proper selection of spring rates (pounds per inch or pounds per foot of deflection) to each engine mounting location.

Whether the aircraft is level, dives spins, or inverts—seven equations give the engine support reactions

The general type of mounting used for turbo-prop engines is the three-point mounting system (Fig. 1). Two mounting points are made coaxial in the side direction and are placed forward on the engine structure. The third mounting point is placed on the aft or rearward portion of the engine structure. The reactions acting at the engine's three mounting points must be determined accurately because the engine's structural design is completely dependent upon their magnitude.

At the two forward mounting points, vertical (z plane), side (y plane), and fore-and-aft (x plane) loads are carried. At the rear mounting point, only vertical and side loads are carried. Since the rear mounting point does not carry fore-and-aft loads, longitudinal thermal growth between the front and rear mounts may occur freely with no load being induced in the engine or airframe. Thermal growth in the side direction is taken by either compression or shear in the rubber mounts or by designing one of the two front mounts so that no sidewise restraint will take place; that is, no side load will be carried. Thermal growth in the vertical direction need not be considered.

Flight Loading Conditions

Spins, dives and pull-outs, sudden sharp-edged wind gusts, rough landings, and inverted flight are some of the flight conditions an aircraft encounters. These flight conditions cause high loadings on an aircraft's engine structure and, combined with engine operating loads, provide the basis for engine structure design.

The combination of forces which may act on an engine are many and can never be predicted for every possible flight condition. For this reason, flight loading envelopes are used with analysis of the

envelope extremities being used as design criteria. The *flight loading envelopes* are three dimensional diagrams in which the three co-ordinates are vertical, side, and fore-and-aft inertia loads. Given volumes within these inertia envelopes also have angular velocities and accelerations specified to be acting concurrently with the inertia loads.

The basic loads induced in an aircraft engine due to various flight conditions are "G" loading, gyroscopic moments, thrust loads, propeller torque loads, propeller shear load and moment, spinner shear load, and pitching and yawing moments.

"G" loading is encountered when any body at rest is caused to move in a manner to change its direction or orientation. Newton's Second Law of Motion states that the force required to accomplish this movement is proportional to its mass times its acceleration. The force obtained, therefore, is the inertia force acting and the ratio of this force to the static or "dead" weight of the body is referred to as the "G" load. For example, when an aircraft executes a turn, force is required to pull each part of the aircraft and its engine into a curved path. This force may be many times the actual weight of the part. If the inertia force is five times the actual part weight, the loading would be called a 5 "G" load.

When a rotating part is turned with an angular velocity about any axis other than its own axis of rotation, a gyroscopic moment is produced. For a mass as large as the propeller of a turbo-prop engine, the gyroscopic moment is often the primary load governing engine structural design.

The propeller of a turbo-prop engine rotates at several hundred revolutions per minute and in so doing produces a thrust load. The resistance of the air to the rotating propeller produces large propeller torque loads which must be reacted by the engine and airframe structure. When the propeller is caused to move through the air so that its axis of rotation is not parallel to the impinging air stream, aerodynamic forces (created by varying angles of attack on the airfoil sections of the blades in making one revolution) cause a side or vertical propeller shear load and moment.

Air flow over the propeller's spinner, when the spinner is moving at an angle to the impinging air stream, causes a side or vertical spinner shear load which is

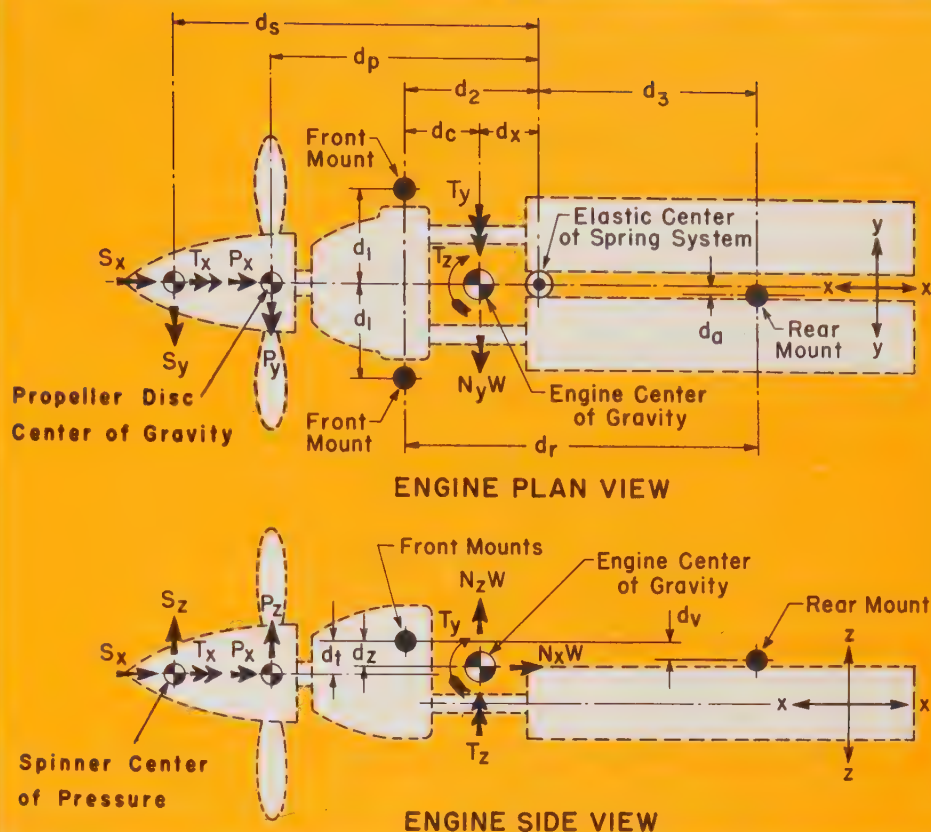


Fig. 2—Flight conditions encountered by an aircraft, such as spins, dives, and pitching and yawing maneuvers cause high loadings on the engine's structure and require reaction at either two or three of the mount points.

located at the spinner center of pressure.

Pitching and yawing angular accelerations on the engine produce pitching and yawing moments about the engine's center of rotation. In pitch, the center of rotation usually is considered to be the center of gravity of the engine.

Each of the basic loads induced in an aircraft engine due to flight conditions requires reaction at either two or three of the engine mounting points. Fig. 2 shows a plan and elevation view of a turbo-prop engine with vectors representing the basic loads which act on the engine. It should be noted that the vectors are shown acting in the positive direction for the sign convention used and do not necessarily indicate the true direction of actual loads and moments.

Methods of Determining Reactions

The evaluation of reactions due to the loads and moments acting in the vertical and fore-and-aft directions on the engine

- S_x = spinner air load (aft)
- S_y = spinner air load (side)
- S_z = spinner air load (vertical)
- T_x = propeller torque
- P_x = propeller and engine thrust (aft)
- P_y = propeller air load (side)
- P_z = propeller air load (vertical)
- T_y = inertia moment due to pitch or gyroscopic moment due to yaw
- T_z = inertia moment due to yaw or gyroscopic moment due to pitch
- W = weight of power plant
- N_x = inertia or "G" load (aft)
- N_y = inertia or "G" load (side)
- N_z = inertia or "G" load (vertical)

Sign Convention:

(+) = Up, Aft, and Left (from rear)

Use left hand rule for moment vectors T_x , T_y , T_z

may be accomplished by using the three basic equations of static equilibrium: $\Sigma M = 0$, $\Sigma F_v = 0$, and $\Sigma F_h = 0$. These basic equations may be used because there are essentially only two support points in the xz plane; the two front mounts, because they are coaxial, are one support point and the rear mount is the other. It is possible to sum moments about either the front or rear mounts and to establish the reaction at the other mount location. Thus, the evaluation of

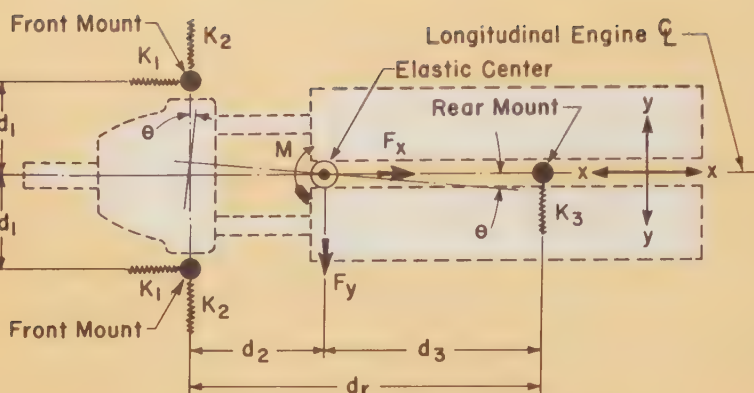


Fig. 3—The determination of reactions according to the spring rates of the engine, mounts, and airframe makes use of the spring system and the system's elastic center. The spring system refers to the combined action of the engine, mounts, and airframe. The elastic center of the spring system refers to the point about which rotation (θ) in the spring system will occur when forces F_x and F_y and the moment M acting about the elastic center are applied.

K_m = spring rate of mounts (lb/in.)

K_a = spring rate of airframe (lb/in.)

K_e = spring rate of engine (lb/in.)

$K_1 = \frac{K_{m_x} K_{a_x}}{K_{m_x} + K_{a_x}}$ = combined spring rate of front mounts and airframe—fore and aft direction (lb/in.)

$K_2 = \frac{K_{m_y} K_{a_y}}{K_{m_y} + K_{a_y}}$ = combined spring rate of front mounts and airframe—side direction (lb/in.)

$K_3 = \frac{K_{m_y} K_{a_y} K_{e_y}}{K_{m_y} K_{e_y} + K_{a_y} K_{e_y} + K_{m_y} K_{a_y}}$ = combined spring rate of rear mount, airframe, and engine structure (between front and rear mounts) (lb/in.)

$K_{3'} = \frac{K_{m_y} K_{a_y}}{K_{m_y} + K_{a_y}}$

d_r = fore and aft distance between front and rear mounts (in.)

d_1 = one-half distance between front mounts (in.)

$d_2 = \frac{K_3 d_r}{K_2 + K_3}$ = fore and aft distance between elastic center and front mount (in.) (K_2 = sum of both front mount spring rates in side direction)

d_3 = fore and aft distance between elastic center and rear mount (in.)

θ = rotation of engine about elastic center

F_x = total fore and aft load acting at elastic center

F_y = total side load acting at elastic center

M = total moment acting around elastic center

reactions due to vertical loads and moments in the xz plane may be direct because the engine structure is statically determinate for this type of loading.

The loads and moments applied in the side direction (xy plane), however, cause reactions which make the engine a statically indeterminate structure. The three equations of static equilibrium, therefore, are not sufficient for determining the reactions. Another approach is necessary. The approach to be used is to determine reactions according to the spring rates of the engine, mounts, and airframe.

Spring System

The determination of reactions according to the spring rates of the engine, mounts, and airframe makes use of the spring system and the system's elastic center.

The *spring system* refers to the combined action of the engine, mounts, and airframe. All three spring actions require consideration in referring to the spring system since the engine, mounts, and airframe all have different deflections for given values of applied loads. The spring rates of each are considered to act at the mounting points on the engine and, since this is true, the spring system considered consists of the following:

- At each of the two front mounts, the

spring action consists of the side and the fore-and-aft spring rates of the mounts and the airframe. The spring rate of the engine is neglected at these two mounting points because the deflection of the engine, forward of these points, does not affect the magnitude of the reactions. The deflection of the engine between the two front mount points is extremely small and the spring rate, therefore, is extremely large. In view of this, the spring rate between the two front mounts is considered to be infinite and may be neglected.

- At the rear mount, the spring action consists of the side spring rate at the rear mount, airframe, and engine. The engine spring rate is load per unit deflection which exists between the front and rear mounts on the engine in the side direction. The fore-and-aft spring rate at the rear mount is zero since there is no fore-and-aft restraint on the engine at the rear mount point.

The *elastic center* of the spring system refers to the point about which rotation in the spring system will occur when forces are applied to the system. It follows, therefore, that loads acting through the elastic center cause no rotation and that only moments about the elastic

center will cause rotation in the spring system. It is necessary to locate accurately the elastic center in order to find how loads are distributed in the statically indeterminate side loading conditions.

Locating the elastic center is actually quite simple in the three-point mounting system. Fig. 3 shows a plan view of the elastic center's location in a turbo-prop engine and the forces acting at the elastic center. Since the engine is statically determinate for forces acting in the vertical or xz plane, the plan view or xy plane is the only one in which the elastic center must be located.

In the plan view, there are only two fore-and-aft reactions. These are at the front mounts which, as a rule, are located symmetrically about the engine's longitudinal centerline and are always of equal magnitude. The elastic center, therefore, must be located on the longitudinal centerline of the engine. The only sidewise reactions are those at the front and rear mounts. Since the two front mounts are coaxial, one side reaction may be considered as acting at the two front mounts. Since there is but one rear mount, this provides the only other sidewise reaction. The elastic center is located longitudinally as the point at which the resultant of the two side reactions would act. The inverse proportion method for determining a resultant force lends itself readily to locating this point.¹

REACTIONS (SIDE DIRECTION: Y PLANE)

Since the two reactions R_{fy_r} and R_{fy_l} acting in the side direction are coaxial, one side reaction may be considered as acting at the two front mounts. This reaction is designated as $R_{fy_{lr}}$. The sum of $R_{fy_{lr}} + R_{ry}$ is the total side reaction which must be equal in magnitude and opposite in sign to the force F_y . By summing moments about the rear mount and considering only the reactions $R_{fy_{lr}}$ and R_{ry} and the force F_y , the following equations may be written for reactions acting in the side direction:

$$\begin{aligned}\Sigma M_{r_z} &= 0 \\ F_y d_3 + R_{fy_{lr}} d_r &= 0 \\ R_{fy_{lr}} &= -F_y(d_3/d_r)\end{aligned}$$

Also

$$\begin{aligned}\Sigma F_y &= 0 \\ F_y + R_{fy_{lr}} + R_{ry} &= 0 \\ R_{ry} &= -F_y(1 - d_3/d_r).\end{aligned}$$

REACTIONS (FORE AND AFT DIRECTION: X PLANE)

The sum of $R_{fx_r} + R_{fx_l}$ is the total fore and aft reaction which must be equal in magnitude and opposite in sign to F_x . By summing moments about the left front mount and considering only the reactions R_{fx_l} and R_{fx_r} and the force F_x , the following equations can be written for reactions acting in the fore and aft directions:

$$\begin{aligned}\Sigma M_{f_{z_l}} &= 0 \\ F_x d_1 + R_{fx_r}(2d_1) &= 0 \\ R_{fx_r} &= -F_x d_1 / 2d_1 = -F_x / 2.\end{aligned}$$

Also

$$\begin{aligned}\Sigma F_x &= 0 \\ F_x d_1 + R_{fx_r} + R_{fx_l} &= 0 \\ R_{fx_l} &= -F_x - R_{fx_r} \\ R_{fx_l} &= -F_x - (-F_x / 2) \\ R_{fx_l} &= -F_x / 2.\end{aligned}$$

MOMENT ACTING ABOUT ELASTIC CENTER

The remaining force to distribute as reaction is the total moment acting about the elastic center. This moment can be determined by multiplying the reactions at the front and rear mounts in the side and the fore and aft direction by their moment arm to the elastic center.

$$M = 2R_{fx} d_1 + R_{fy} d_2 + R_{ry} d_3$$

Table I—The calculations for determining the reactions acting in the side and the fore-and-aft directions and the moment acting about the elastic center are based on the forces shown in Figs. 1 and 3.

$$M = 2R_{fx} d_1 + R_{fy} d_2 + R_{ry} d_3$$

The reaction at each mount is equal to the spring rate of the mount times the mount's deflection. The moment caused by each reaction may be stated as:

$$\begin{aligned}R_{fx} d_1 &= K_1 d_1 \theta d_1 = K_1 d_1^2 \theta \\ R_{fy} d_2 &= K_2 d_2 \theta d_2 = K_2 d_2^2 \theta \\ R_{ry} d_3 &= K_3 d_3 \theta d_3 = K_3 d_3^2 \theta.\end{aligned}$$

The total moment M , therefore, is:

$$M = 2K_1 d_1^2 \theta + K_2 d_2^2 \theta + K_3 d_3^2 \theta.$$

Table II—The total moment M acting about the elastic center may be stated in terms of the spring rate and the deflection of each mount.

$$\text{Total Moment} = M = 2K_1 d_1^2 \theta + K_2 d_2^2 \theta + K_3 d_3^2 \theta$$

$$\text{Moment caused by front mount reaction (fore & aft)} = K_1 d_1^2 \theta$$

$$\text{Moment caused by front mount reaction (side direction)} = K_2 d_2^2 \theta$$

$$\text{Moment caused by rear mount reaction (side direction)} = K_3 d_3^2 \theta$$

Proportion of total moment carried at each front mount (fore and aft)

$$\frac{K_1 d_1^2 \theta}{2K_1 d_1^2 \theta + K_2 d_2^2 \theta + K_3 d_3^2 \theta} = \frac{M_1}{M} \quad (\text{unitless ratio})$$

cancelling θ terms gives

$$\frac{K_1 d_1^2}{2K_1 d_1^2 + K_2 d_2^2 + K_3 d_3^2} = \frac{M_1}{M}$$

$$\text{let } 2K_1 d_1^2 + K_2 d_2^2 + K_3 d_3^2 = \Sigma K d^2$$

therefore

$$\frac{M_1}{M} = \frac{K_1 d_1^2}{\Sigma K d^2}$$

Proportion of total moment carried at each front mount (side direction)

$$\frac{K_2 d_2^2 \theta}{2K_1 d_1^2 \theta + K_2 d_2^2 \theta + K_3 d_3^2 \theta} = \frac{M_2}{M}$$

$$\frac{M_2}{M} = \frac{K_2 d_2^2}{\Sigma K d^2}$$

Proportion of total moment carried at rear mount (side direction)

$$\frac{K_3 d_3^2 \theta}{2K_1 d_1^2 \theta + K_2 d_2^2 \theta + K_3 d_3^2 \theta} = \frac{M_3}{M}$$

$$\frac{M_3}{M} = \frac{K_3 d_3^2}{\Sigma K d^2}$$

TABLE 3

Table III—A definite proportion of the total moment M is carried at each mount. The proportion of the total moment at each front mount carried in the fore-and-aft direction is M_1 and in the side direction is M_2 . The proportion carried at the rear mount in the side direction is M_3 . Calculations for determining the proportions are based on the spring rate and deflection of each mount.

FRONT MOUNT REACTION (Fore & Aft) DUE TO TOTAL MOMENT

$$R_{f_{x_l}} = -R_{f_{x_r}} = M/d_1 (K_1 d_1^2 / \Sigma K d^2) = M(K_1 d_1 / \Sigma K d^2)$$

FRONT MOUNT SIDE REACTION DUE TO TOTAL MOMENT

$$R_{f_{y_{lr}}} = M/d_2 (K_2 d_2^2 / \Sigma K d^2) = M(K_2 d_2 / \Sigma K d^2)$$

REAR MOUNT SIDE REACTION DUE TO TOTAL MOMENT

$$R_{r_y} = -M/d_3 (K_3 d_3^2 / \Sigma K d^2) = -M(K_3 d_3 / \Sigma K d^2)$$

TOTAL REACTIONS AT EACH MOUNT :

LEFT FRONT MOUNT TOTAL REACTION (Fore and Aft)

$$R_{f_{x_l}} = -F_x/2 + M(K_1 d_1 / \Sigma K d^2)$$

RIGHT FRONT MOUNT TOTAL REACTION (Fore and Aft)

$$R_{f_{x_r}} = -F_x/2 - M(K_1 d_1 / \Sigma K d^2)$$

RIGHT AND LEFT FRONT MOUNT TOTAL SIDE REACTION

$$R_{f_{y_{lr}}} = -F_y (d_3/d_r) + M(K_2 d_2 / \Sigma K d^2)$$

REAR MOUNT TOTAL SIDE REACTION

$$R_{r_y} = -F_y (1 - d_3/d_r) - M(K_3 d_3 / \Sigma K d^2)$$

The location of the elastic center, therefore, is completely defined in the plan view.

Determining Engine Mount Reactions Caused by Loads Acting at the Elastic Center

All loads acting on the turbo-prop engine may be translated to the elastic center so that distribution of the total forces F_x and F_y and the total moment M will constitute the solution necessary for analysis of an actual engine's loading. The forces F_x and F_y may be expressed directly in terms of reactions at the front and rear mounts.

In the calculations to be used for determining engine mount reactions, R will designate reaction. The first subscript will designate location, either the front f or rear r mount. The second subscript will designate the plane, either x , y , or z , and, therefore, the direction in which the reaction takes place. The third subscript, used only for the front mount reactions, will designate whether the reaction is at the right or left front mount as viewed from the top of the engine looking toward its forward end.

The first calculations necessary per-

tain to determining the reactions acting in the side direction (y plane) and in the fore-and-aft direction (x plane) and the total moment M acting about the elastic center. Table I shows the calculations necessary. These calculations are based on the reactions and forces shown in Figs. 1 and 3.

In Fig. 3, Θ represents the rotation of the engine about the elastic center and K_1 , K_2 , and K_3 represent the spring rate at each mount. The deflection of each of the mounts from the elastic center is $d_1\Theta$, $d_2\Theta$, and $d_3\Theta$. Since the reactions are equal to the spring rate of each mount times the mount's deflection it is possible to rewrite the equation for the total moment M caused by each reaction. Table II shows the calculations leading to the establishment of a total moment equation based on the spring rate and deflection of each mount.

The total moment equation calculated in Table II is based on the assumption that the engine is rigid enough so that Θ (angular engine rotation about the spring system elastic center) times d (normal distance from the elastic center to the line of action of each respective reaction) will be the moment absorbed

Table IV (Left)—The total reactions acting at the mount points in the side and the fore-and-aft directions are equal to the reactions caused by the forces F_x and F_y , plus the reactions due to the total moment M .

LEFT FRONT MOUNT FORE AND AFT REACTION (Equation 1)

$$R_{f_{x_l}} = -\frac{1}{2} (S_x + P_x + N_x W) - \frac{K_1 d_1}{\Sigma K d^2} [-d_s S_y - d_p P_y - N_y W d_x + T_z]$$

RIGHT FRONT MOUNT FORE AND AFT REACTION (Equation 2)

$$R_{f_{x_r}} = -\frac{1}{2} (S_x + P_x + N_x W) + \frac{K_1 d_1}{\Sigma K d^2} [-d_s S_y - d_p P_y - N_y W d_x + T_z]$$

FRONT MOUNT SIDE REACTION (Equation 3)

$$R_{f_y} = -\frac{d_3}{d_r} (S_y + P_y + N_y W) + \frac{K_2 d_2}{\Sigma K d^2} [-d_s S_y - d_p P_y - N_y W d_x + T_z]$$

REAR MOUNT SIDE REACTION (Equation 4)

$$R_{r_y} = (1 - \frac{d_3}{d_r}) (S_y + P_y + N_y W) - \frac{K_3 d_3}{\Sigma K d^2} [-d_s S_y - d_p P_y - N_y W d_x + T_z]$$

Table V—Basic equations 1 through 4 completely define the external support reactions acting on the engine in the side and the fore-and-aft directions for any possible flight loading condition.

at each of the mounts. This is a very good assumption in practice because the value of the rear mount side spring rate is usually very small compared to the engine side spring rate between the front and rear mounts. The error introduced in the calculations by this assumption, therefore, is negligible.

Each mount carries a proportion of the total moment M . At each front mount the proportion of the moment carried in the fore-and-aft direction is designated as M_1 and the proportion of the total moment carried in the side direction is designated as M_2 . The proportion of the total moment carried at the rear mount in the side direction is designated as M_3 . Table III shows the calculations necessary to determine the proportion of the total moment carried by each mount.

The next step is to determine the total reactions acting in the fore-and-aft and the side directions. Previous calculations (Table I) have established the reactions at each mount due to the forces F_x and F_y . These reactions must be added to the reactions at each mount caused by the moment M . The calculations of Table III have established equations for the

REAR MOUNT VERTICAL REACTION (Equation 5)

The vertical reaction for the rear mount is determined by summing moments about a transverse or sidewise axis containing the centerline of the two front mounts.

$$R_z = \frac{1}{d_f} [-d_f(S_x + P_x) - N_z W d_c - N_x W d_z + T_y + S_z(d_s - d_2) + P_z(d_p - d_2)]$$

RIGHT FRONT MOUNT VERTICAL REACTION (Equation 6)

The vertical reaction for the right front mount is determined by summing moments about a fore and aft axis through the left front mount and parallel to the longitudinal centerline of the engine.

$$R_{z_r} = \frac{1}{2d_f} [-d_f(S_z + P_z + N_z W) + d_f(S_y + P_y) + d_z N_y W - T_x - (d_l - d_a)R_z + R_{y_f} d_v]$$

LEFT FRONT MOUNT VERTICAL REACTION (Equation 7)

The vertical reaction for the left front mount is determined by summing about a fore and aft axis through the right front mount parallel to the longitudinal centerline of the engine.

$$R_{z_l} = -\frac{1}{2d_f} [-d_f(S_z + P_z + N_z W) + d_f(S_y + P_y) + N_y W d_z + T_x + (d_l - d_a)R_z + R_{y_f} d_v]$$

proportion of the total moment M carried by each mount in the side and the fore-and-aft directions. Multiplying each side of these equations by the total moment M will give the moment carried by each mount and dividing by the length of the moment arm from the elastic center to each mount will give the reaction at each mount due to the total moment M . The calculations necessary to determine the total reactions at each mount are shown in Table IV.

It is now necessary to obtain proper values for F_x , F_y , and M . These values, when substituted into the equations established for the total reaction at each mount in Table IV, will completely define the external support reaction acting on the engine in the side and the fore-and-aft directions.

Fig. 2 shows all the possible loadings that may be imposed on an engine during flight. From Fig. 2 it may be seen that F_x , F_y , and M have the following values:

$$F_x = S_x + P_x + N_x W$$

$$F_y = S_y + P_y + N_y W$$

$$M = d_s P_x - d_p P_y - N_y W d_x + T_z$$

Substituting the above values for F_x , F_y , and M into the total reaction equations of Table IV will give four basic formulae or relationships which will define completely the external support reactions acting on the engine in the side and the fore-and-aft directions. Table V shows the substitutions and resulting four basic equations.

Vertical Reactions at Front and Rear Mount Points

The four basic equations in Table V completely define the external support reactions acting on the engine in the side and the fore-and-aft directions. It is now necessary to determine the three remaining reactions acting vertically at each of the two front mounts and the rear mount. Table VI shows the calculations necessary to determine the three vertical reactions.

Basic equations 1 through 7 completely define engine external support reactions for any possible combination of flight loading conditions. These equations enable the engineer to proceed with a design analysis of the engine structure. A few comments, however, are applicable in regard to the approach used in initial engine design.

As a rule, it is impossible to determine accurately the exact spring rate of engine, mounts, and airframe during the initial stages of engine structure design. As a result, the approach used is to estimate spring rates based on past experience for similar engines and all possible data that can be obtained on intended applications. Experience has shown that by using this approach the reactions calculated initially are very close to those obtained later in the engine's development program when exact spring rate values become available. Experience has also shown that the value of the rear mount spring rate K_3 may be taken as the value K_3' (indicated in Fig. 3 legend) because, as discussed earlier, the relative engine spring rate

Table VI (Left)—Basic equations 5 through 7 completely define the external support reactions acting vertically on the engine at each of the two front mounts and the rear mount.

DIVE AND PULL-OUT LOADS

N_z = vertical inertia load = IOG

S_z = vertical spinner air load = +5,100 lb

P_z = vertical propeller air load = +21,000 lb

P_x = engine thrust forward = -7,050 lb

T_x = propeller torque = $\pm$ 135,000 in. lb

T_y = pitching inertia moment of engine = +400,000 in. lb

Table VII—Substitution of the values shown for dive and pull-out loads into the seven basic equations of Tables V and VI provides the design engineer with information as to the magnitude of the reactions caused by this type of flight condition.

between the front and rear mounts is very high.

The seven basic equations appear to be long and perhaps cumbersome. The fact is, however, that most combined flight loading conditions encountered contain but few of the terms involved in the equations. As an example, a typical flight loading condition used in design is the dive and pull-out loading condition. Table VII shows typical values for dive and pull-out loads. When these values are substituted into the seven equations, the number of terms involved are only one or two in number for most of the reactions.

Summary

The use of spring rates for proportioning loads to a turbo-prop aircraft engine's mounting locations provides the design engineer with seven basic equations for evaluating all external support reactions for any possible combination of flight loading conditions. These reactions then are used in engine structure design. Without this method of proportioning loads, less accurate means for determining reactions would be used with the possibility that improper design would result, adding an unnecessary weight penalty to the engine.

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A Discussion of Major Factors Affecting the Fabrication of Rubber Products by Extrusion

The design engineer frequently uses rubber products as engineering materials having specific properties which fill many exacting requirements. Rubber products used as engineering materials endure where no other material can qualify under the abusive action of repeated impact, continuous flexing, vibration, abrasion, and the destructive action of chemicals, heat, and oils. The majority of rubber products used as engineering materials is usually of complex cross section and some can be fabricated most advantageously by extrusion. Although the principle of the extrusion process is basically simple, many factors must be considered before the final end product is realized. Such factors which must be considered by the engineer include the proper choice of the rubber compound to be extruded, the design of the extruding die, and the handling of the rubber compound before and after it has been extruded.



Fig. 1—The extrusion process makes possible the successful fabrication of many rubber products of intricate cross section for use as engineering materials.

THE extrusion process represents one of the oldest and most useful processes employed in the fabrication of rubber products. It is a process which has been improved constantly through the years and makes possible the fabrication of many rubber products of intricate cross section. Fig. 1 shows a few of the cross sections of rubber products which are fabricated by the extrusion process at

Inland Manufacturing Division.

Briefly, the process of fabricating rubber products by extrusion involves a rotating tuber screw which forces a rubber compound through an extruding die having an aperture shaped to produce the desired cross section. The basic idea behind the extrusion process is quite simple but there are many factors which must be taken into consideration when



deciding upon the rubber compound to be used for extruding, the design of the extruding die, and the sequence of operations before and after the rubber compound is extruded.

Rubber Compounds Best Suited for the Extrusion Process

Rubber compounds used for extruding contain whatever pigments, age resistors, accelerators, or other ingredients the extruded product requires. Some extrusions, such as refrigerator door sealing strips, must be made from rubber compounds that are tasteless, odorless, and of suitable color. Other extrusions must be made from rubber compounds which have good resistance to oils, sunlight, heat, or chemicals.

Natural rubber, GR-S, neoprene, buna N, polyacrylate, and silicone are rubberlike polymers which can be extruded satisfactorily into a variety of cross sections. Natural rubber has excellent properties whenever a minimum of energy absorption is desired and long flexing life is required. GR-S (government rubber-styrene), a synthetic rubber developed during World War II, has good abrasion and oxidation resistance properties and has excellent resistance to hot-water swelling. Neoprene has excellent resistance to sunlight and good resistance to oils, heat, and aging. Neoprene also has excellent adhesion to woven fabrics. Silicone rubber, made from silicon, oxygen, hydrogen, and carbon, possesses extraordinary heat resistance and is used for extrusions which will be subjected to elevated temperatures. Silicone rubber also remains flexible and resilient down to a temperature of -70°F .

By THOMAS O. MATHUES

Inland
Manufacturing
Division

A refrigerator door
sealing strip serves
as a specific example

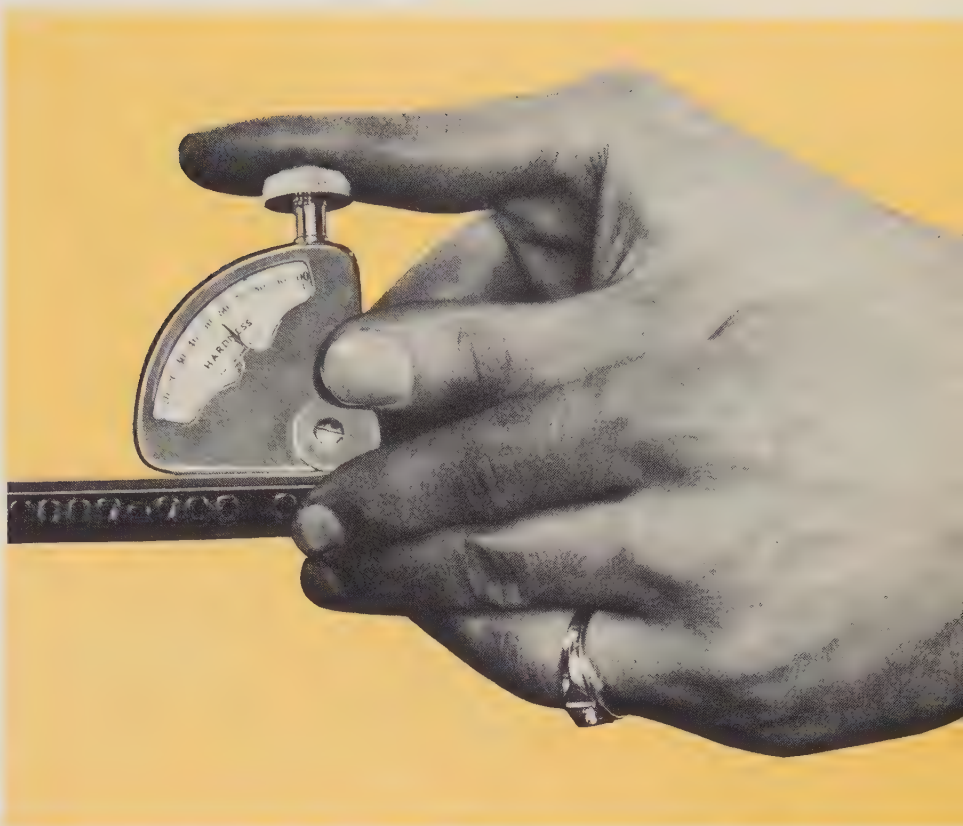


Fig. 2—A Shore "A" rubber hardness measurement is taken by pressing the indenter point and pressure foot of the instrument firmly onto a flat piece of rubber. A nearly instantaneous reading is obtained.

In general, hard-rubber compounds can be extruded to thinner sections more easily than soft-rubber compounds and low and medium tensile strength compounds can be more easily extruded than high tensile strength compounds. High tensile strength extrusions, over 2,000 psi, can be made more easily from natural rubber or neoprene than from the other synthetic rubber compounds. Silicone rubber extrusions must be baked at high temperatures for long periods of time before optimum physical characteristics can be realized.

The hardness of a rubber compound is measured by an instrument called a Shore durometer (Fig. 2). The Shore "A" durometer has an indenter point in the shape of a truncated cone. The instrument is pressed against the rubber compound to be tested for hardness until a bearing plate, through which the indenter works, makes contact with the rubber compound surface. A pointer on the durometer indicates the hardness of the rubber compound. If, for example, a rubber compound is tested and the pointer reads 40, the rubber compound is referred to as having a hardness of 40 Shore "A." The maximum durometer hardness of rubber compounds for easy extrusion is around 85 and the minimum is 45, plus or minus 5. Generally, rubber compounds below a hardness of 45 must be supported on special forms until vulcanized.

The effect of the majority of factors affecting the extrusion of rubber products is a matter of judgment for experienced rubber technologists. Certain factors, however, can be related to each other and to the effect they produce on extrusions. In this connection, a chart

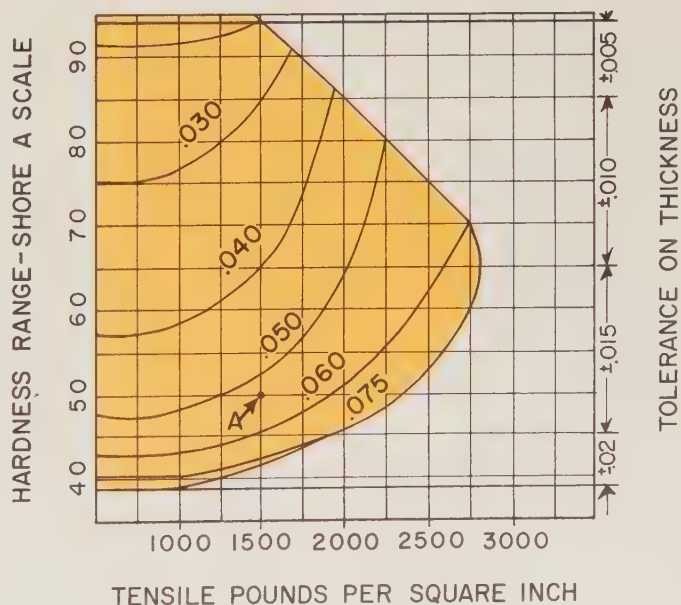


Fig. 3—The development of a chart by Inland Manufacturing Division's engineers relates tensile strength, rubber-compound hardness, and allowable dimensional tolerances to the practical minimum thickness to which a rubber product can be extruded. For example, if an engineer is designing a rubber product which is to have a minimum wall thickness of 0.050 in. and a hardness of 70 Shore "A," reference to the chart shows that the tensile strength of the rubber compound should not exceed 2,100 psi and that a dimensional tolerance of ± 0.010 in. should be specified. As another example, if a rubber product is to be designed of a rubber compound having a hardness of 50 Shore "A" and a tensile strength of 2,000 psi, the minimum practical wall thickness which could be extruded would be 0.075 in. and the dimensional tolerance would be ± 0.015 in.



Fig. 4—The designer of an extruding die must take into consideration the amount of swell and shrinkage for the particular rubber compound being extruded. It is for this reason that the aperture of an extruding die is seldom the shape of the rubber product extruded. The apertures of the extruding dies (top left and right) bear only a general resemblance to the shape of the extruded rubber product.

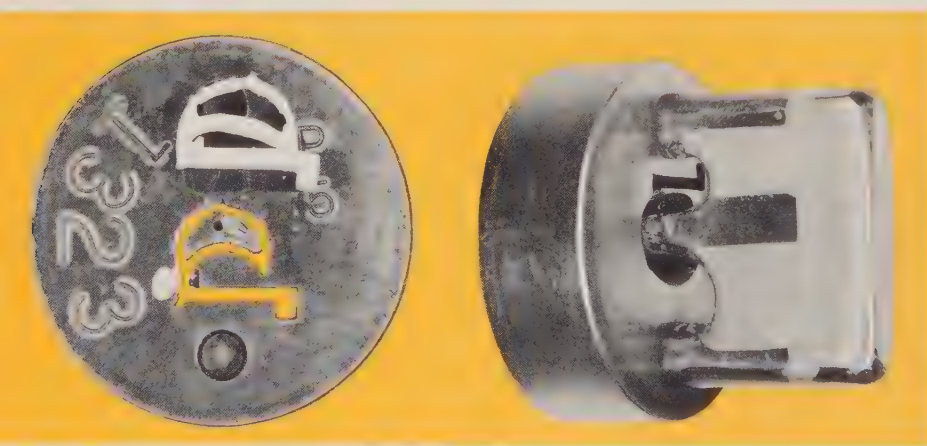


Fig. 5—The bulb section of the extruding die used to extrude a refrigerator door sealing strip (left) is completely isolated from the rest of the die and must be rigidly supported in the back of the die by a mandrel (right).

developed at Inland Manufacturing relates hardness, tensile strength, and allowable dimensional tolerances to the practical minimum thickness which can be satisfactorily extruded (Fig. 3). The chart was developed at the request of the Rubber Development Committee of Fisher Body Division and has been incorporated in that Division's *Body Engi-*

neering Manual. The values shown on the chart (Fig. 3) are for rubber extrusions with good surface finish. If surface finish is not important, the values can be somewhat relaxed.

(When contemplating the use of extrusions made from butyl, polyacrylate, silicone, or some other specialty synthetic, the advice of a competent rubber tech-

nologist should be relied upon in preference to any generalized rules such as are included in this chart.)

Extruding Dies

Extruding dies are usually high-grade steel circular plates with an aperture through which the rubber compound is forced by pressure. The extruding die may be of one-piece construction—the orifice being cut in a solid disc—or it may be made by assembling two or more sections.

There are many factors which must be taken into consideration when determining the size and shape of an extruding die. Allowance must be made for the amount of swell of the extruded rubber compound as it issues from the extruding machine. Also, allowance must be made for the amount of shrinkage that occurs during the curing period. The amount of swell and shrinkage varies with the rubber compound being extruded and soft rubber compounds have a tendency to swell more than hard compounds.

Because of the effect of swell, shrinkage, and other factors on the final profile dimensions of an extrusion, it is necessary that the die designer have a good knowledge of the rubber compound and the manufacturing equipment to be used before attempting to design a die that will produce anywhere near the shape and size desired. Experience and tests guide the engineer in determining the amount the die openings should be enlarged on the entrance (machine) side and in the placement of flow channels to prevent excessive drag and produce a uniform extrusion. The length of the die opening measured back from the exit surface also influences drag.

The shape of the aperture in an extruding die is seldom the same as the shape of the rubber product extruded. This is due primarily to the amount of swelling which can be expected for some rubber stocks (Fig. 4). The die shown in Fig. 4 left is used to produce a nearly rectangular cross section. Examination of the aperture shows that it would have been difficult to predict the exact shape of the rubber product extruded from this die. Similarly, the rubber product shown in Fig. 4 right bears only a general resemblance to the extruding die aperture from which it was produced.

Both of the rubber products shown in Fig. 4 were extruded from soft rub-



Fig. 6—The compounded rubber stock used for a refrigerator door sealing strip is delivered to the extrusion floor on skids. The stock is light-colored and canvas is used to protect the slabs from contamination.

ber compounds and the amount of swelling which took place is quite apparent. If a harder rubber compound stock had been used for extruding, the swelling would have been considerably less and, therefore, more predictable from the start. Harder rubber compounds tend to produce more uniform extrusions and for this reason dimensional tolerances may be held to closer limits.

Extruding dies are used to produce refrigerator door sealing strips (Fig. 5 left). Examination of the picture reveals certain unexpected differences which exist between the die opening and the finished part. It should be noted that

**Nerve* is a term commonly used to denote the qualities of firmness, strength, and elasticity in crude rubber. For example, smoked sheets have nerve while low-grade, soft rubbers lack it. Nerve is lowered or destroyed by milling. (Glossary of Terms Relating to Rubber and Rubber-Like Materials Published by Committee D-11, American Society for Testing Materials, January 1954.)

part of the sealing strip's bulb section is completely isolated and must be supported back in the die by a mandrel (Fig. 5 right). The design of satisfactory mandrel supports for dies when they are necessary can be a very challenging job to the engineer.

Manufacturing Practice

To complete a discussion of factors affecting the quality of finished rubber extrusions, it is necessary to consider the equipment and the sequence of operations employed in the manufacture of extruded rubber products. The practices which Inland Manufacturing utilizes in the fabrication of a refrigerator door sealing strip will serve as a typical example.

The extrusion process begins with the delivery to the extrusion floor of a skid of compounded GR-S rubber slabs (Fig. 6). The slabs, when delivered, are cool (room temperature). Also, the slabs are from one to six days old and have regained a considerable amount of *nerve*.* In order to provide a smooth plastic material for extrusion, the slabs must be warmed and the nerve broken down.

The warm-up of the rubber slabs is accomplished on a two-roll 60-in. long warm-up mill (Fig. 7). From the front

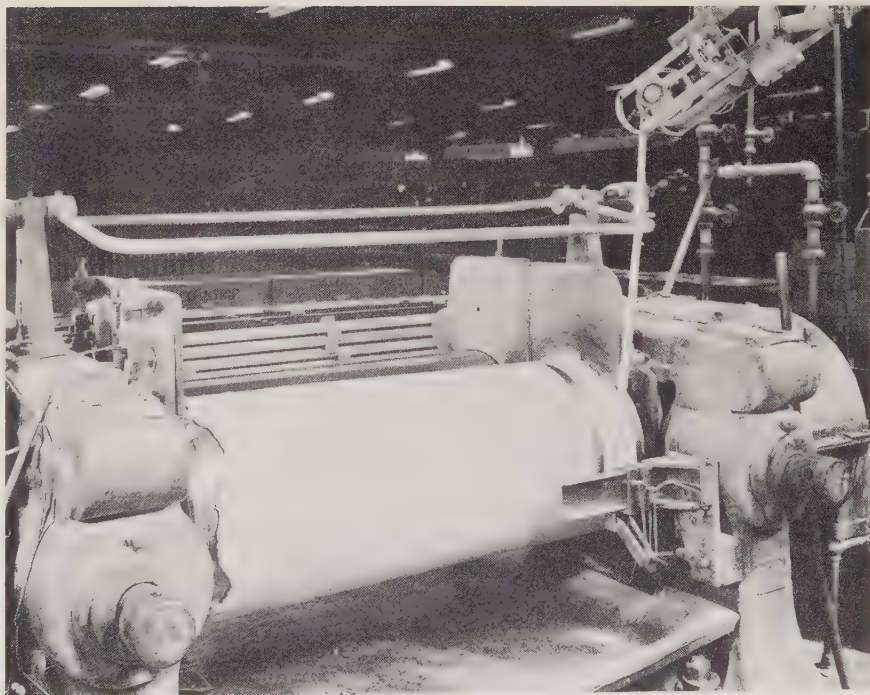


Fig. 7—The compounded rubber stock slabs when used for an extruded refrigerator door sealing strip are from one to six days old and have regained a considerable amount of nerve which must be broken down. The slabs are heated on a 60 in. long, two-roll warm-up mill which breaks down the nerve and insures a smooth plastic material for extrusion. From the front roll of the mill a continuous strip of rubber compound is fed on a roller conveyor to the extruding machines.

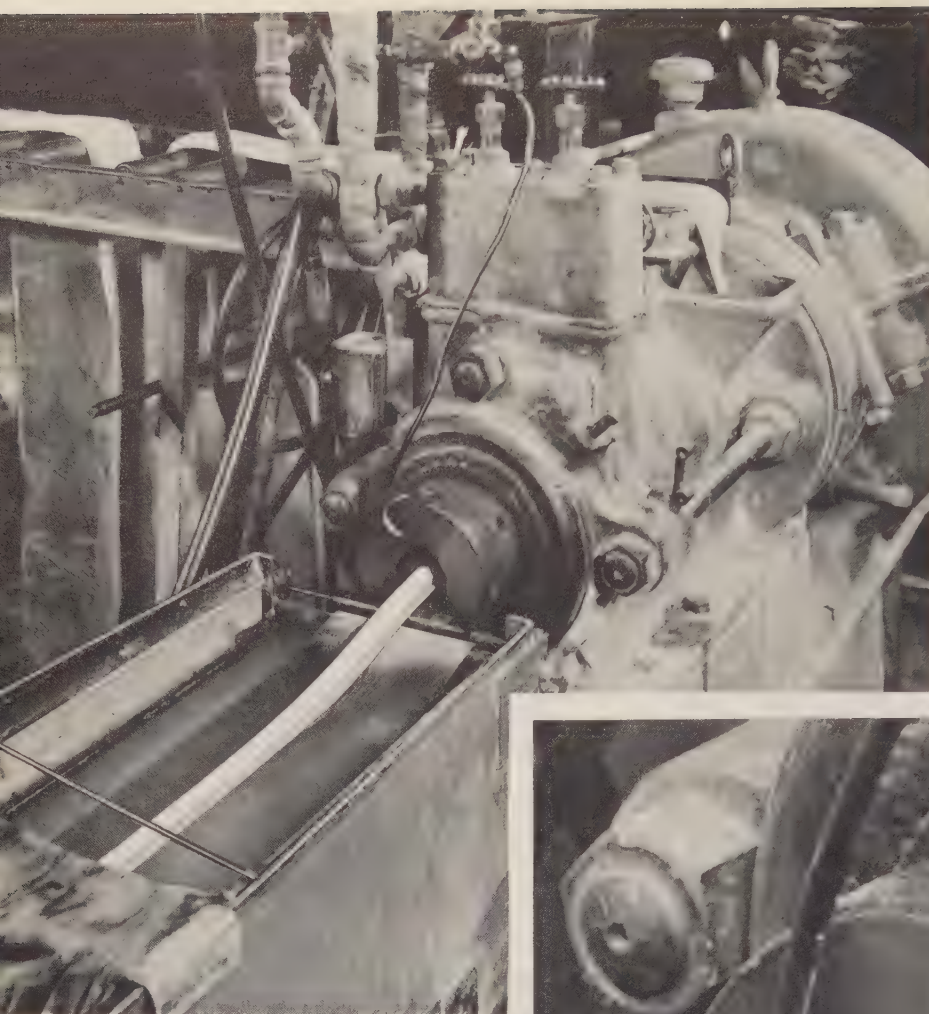


Fig. 8—A continuous strip of rubber compound is fed from a warm-up mill by a roller conveyor to a hopper in the extruding machine. The compound is then fed from the hopper to a rotating tuber screw (not visible) which forces it out through the aperture of the refrigerator door sealing strip extruding die. The extruded sealing strip, upon leaving the die, is very plastic and is quickly cooled by being passed through a water tank which contains soap or a similar ingredient to prevent adjacent areas of the sealing strip from sticking together.

roll of the mill a ribbon of the compounded rubber is fed by means of a narrow roller conveyor to a hopper which is an integral part of the extruding machine (Fig. 8). The warmed-up rubber stock is then fed through the hopper to a rotating tuber screw which forces the rubber out through a heated die opening. By the time the rubber stock passes through the tuber screw and hot die it is very plastic and must be cooled quickly. For this purpose a water tank, which contains soap or some other similar ingredient to prevent adjacent areas of the extruded sealing strip from sticking

together during and after curing, is positioned to receive the strip immediately after it has been extruded. A length of copper tubing connected to the extruding die is used as a gas line for the purpose of providing a gas flame for quickly heating the die at the start of an extrusion run (Fig. 9). Once extrusion is under way the friction created by the rubber passing through the die usually creates sufficient heat and the gas flame is no longer needed.

The sealing strip leaving the extruding machine is in the uncured state and, as such, must be sent to steam curing (vulcanizing) chambers, or retorts. As the sealing strip leaves the water tank it is fed to a take-off belt, cut to a specified length, and then sent to the steam retorts. Extreme care must be exercised when removing the sealing strip from the take-off belt and placing it on the curing trays in order to prevent stretching and

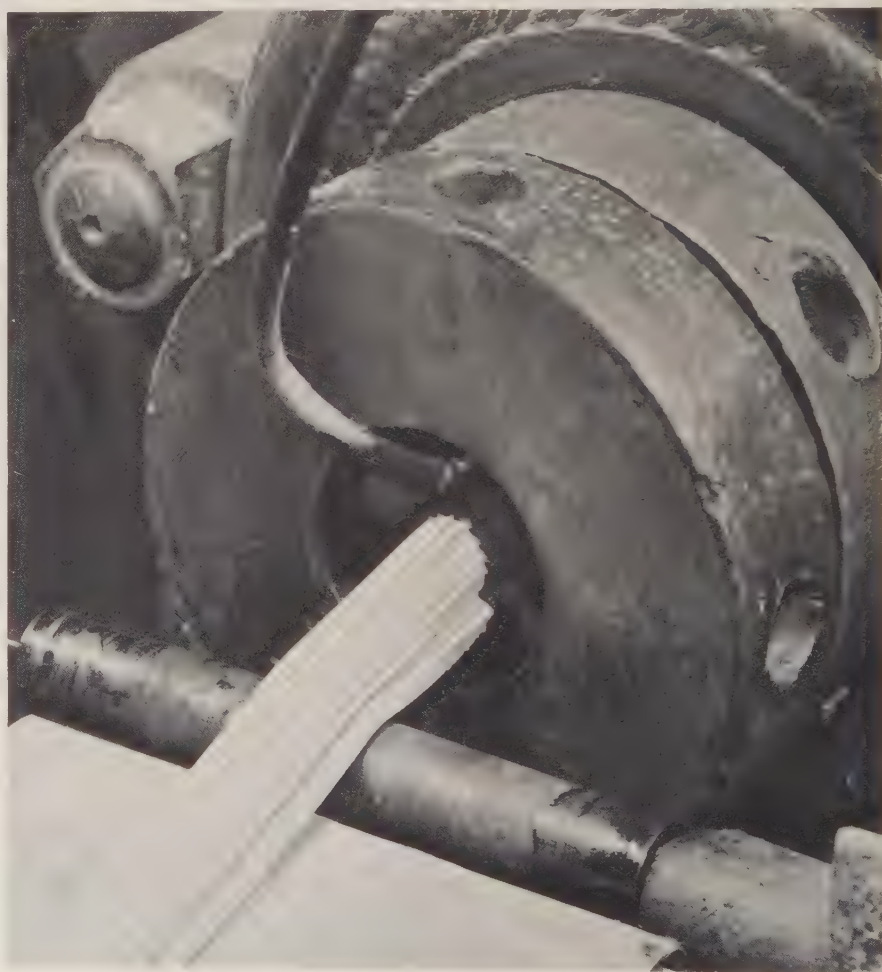


Fig. 9—At the start of an extrusion run, the extruding die must be quickly heated. For this reason a copper tube is used as a line for providing a gas flame. Once extrusion is under way the gas may be shut off, as the friction caused by the rubber passing through the die often creates sufficient heat necessary for the extruding operation.

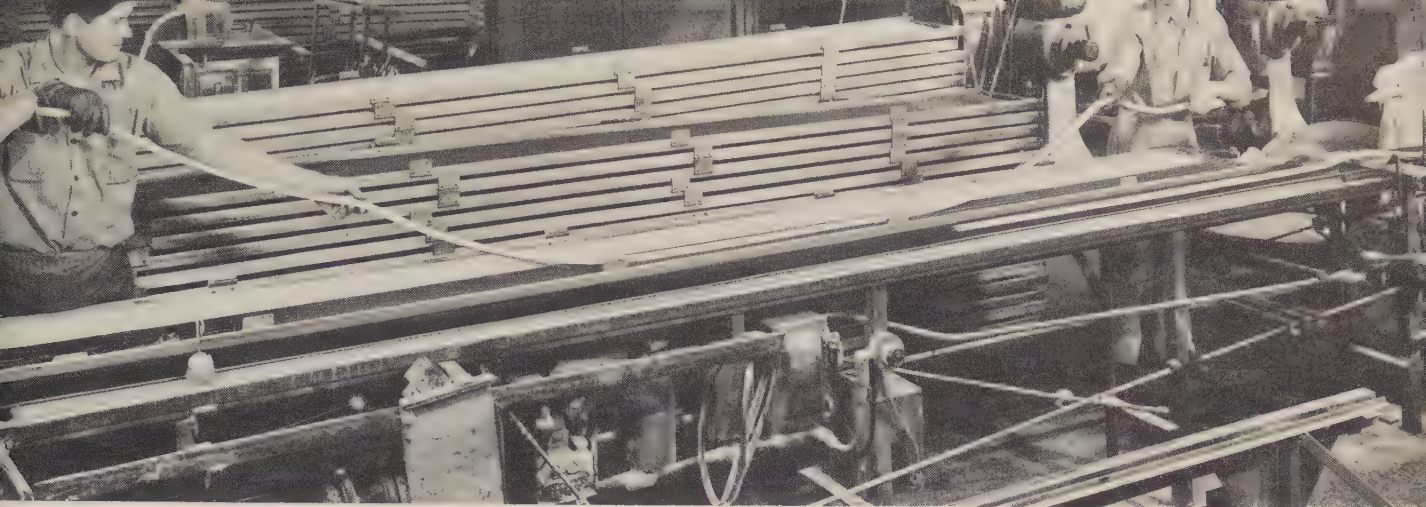


Fig. 10—An extruded refrigerator door sealing strip leaves the extruding machine in an uncured state and must be sent to steam curing chambers. A take-off belt removes the sealing strip from the water tank. The strip is then cut to specified lengths and carefully positioned in contour forms to prevent collapse and distortion during the curing period. The contour forms, placed in curing trays, are then sent to the steam curing chamber

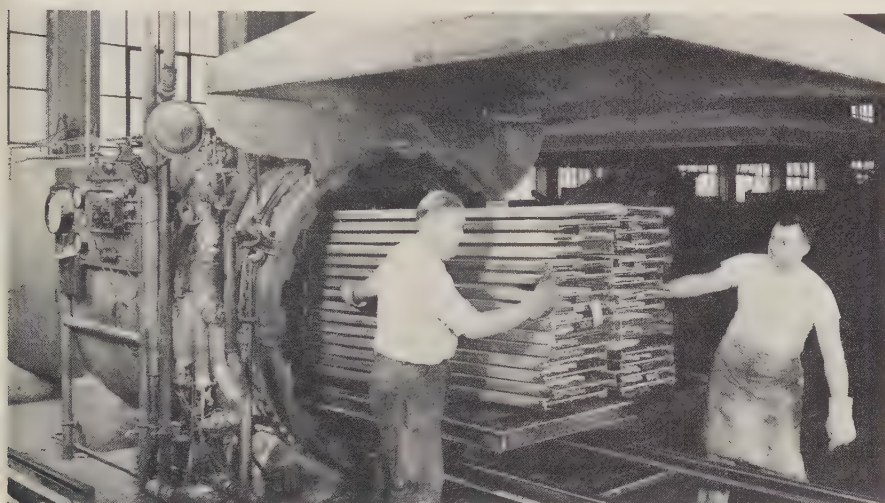


Fig. 11—A refrigerator door sealing strip might be cured under 50 psi steam pressure for 30 min before the rubber compound reaches its optimum physical properties.

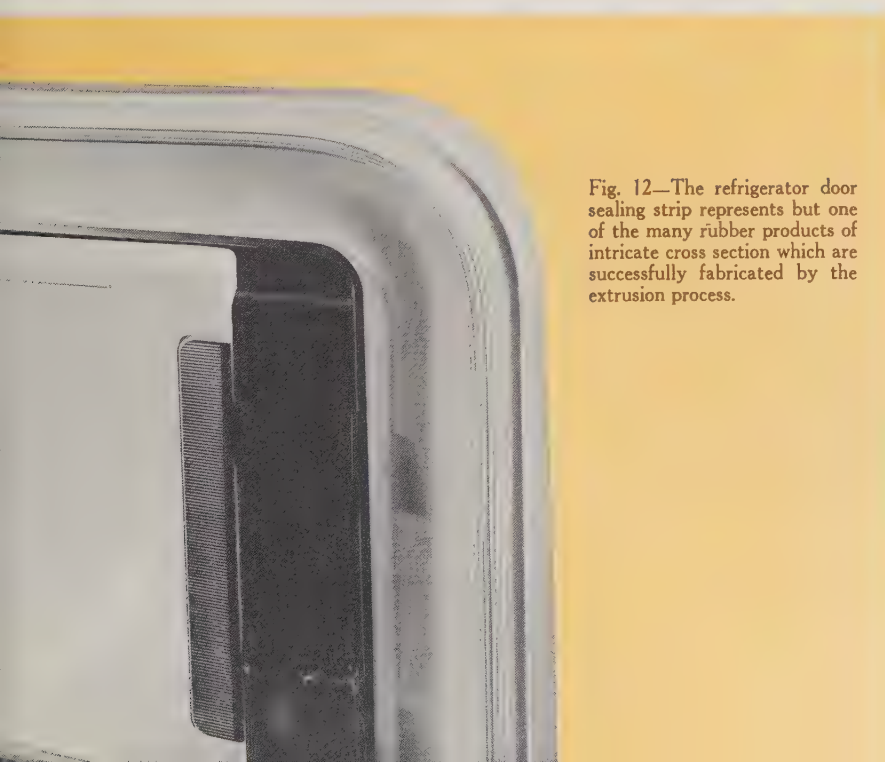


Fig. 12—The refrigerator door sealing strip represents but one of the many rubber products of intricate cross section which are successfully fabricated by the extrusion process.

collapse (Fig. 10). Contour forms are placed in the curing trays which prevent distortion and collapse during the curing period.

In general, the harder and stiffer a rubber compound stock is in the uncured state, the closer dimensional tolerances can be held. It does not always follow, however, that stocks which are hard and stiff when cured are easy to extrude in the uncured state. Here, specific compounding art may be called upon to produce good extruding stocks which may be relatively soft when cured.

After spending a specified period under pressure in the curing retort, the curing trays are then removed (Fig. 11). After being cooled sufficiently, the sealing strips are cut to exact length and other finishing operations are performed before final inspection and packaging. The refrigerator door sealing strip is only one example of the many uses of extruded rubber parts (Fig. 12).

Summary

There are three principal considerations which are important to the engineer if successful fabrication of a rubber product by the extrusion process is to be realized—the rubber compound to be used, the design of the extruding die, and the handling of the rubber compound before and after it has been extruded. Considerable experience and knowledge of rubber compounds are essential when analyzing the many factors involved in fulfilling the specific requirements of an extruded rubber product's design. The successful application of the extrusion principle to rubber product fabrication has resulted in an ever-increasing use of rubber products of seemingly impossible shape as everyday engineering materials.

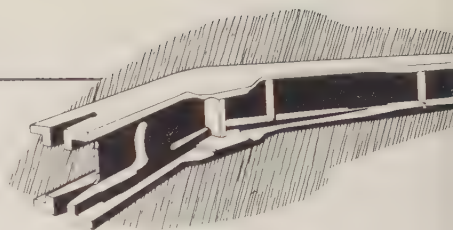
Causes and Control of Distortion during Machining of Aluminum-Alloy Forgings

Warpage during rough machining operations on aluminum-alloy root spar forgings—used in aircraft wing structures—plagued engineers at the Buick-Oldsmobile-Pontiac Assembly Division's Kansas City plant. The distortion was considerable enough to require arduous straightening of the part prior to finish machining. This straightening, in turn, produced cracks in the spar's hinge slot radius and caused frequent production delays. The raw root spar forgings—furnished by an independent supplier—were made of 7075 alloy, a high-strength aluminum alloy which is more difficult to control distortion-wise during machining than lower strength aluminum alloys, mainly because of its inherent high level of internal quenching stresses. These stresses cannot be relieved by the usual stress relief treatments used on ferrous alloys, as such treatments would ruin the effects of the aluminum alloy's previous heat treatment. Engineers on B.O.P.'s F-84F Aircraft Program attacked this distortion problem with several cut-and-try experimental methods, supplemented by a survey of the limited amount of printed literature on this subject then available. The final, successful solution to the distortion problem eliminated the difficult straightening operations and all distortion and cracks, cleared up production delays, resulted in considerable financial and time savings for each spar, and reduced manual labor.

THE root spar raw forgings—as they were received at Buick-Oldsmobile-Pontiac Assembly Division's Kansas City plant from the supplier—were made of 7075 alloy (an aluminum-base alloy containing 5.6 per cent zinc, 2.5 per cent magnesium, 1.6 per cent copper, and 0.3 per cent chromium) and were in the *W* temper condition (*solution heat treated**). As a general procedure, after the spars were received at the Division, prior to any machining operations, an inboard test section or bar was removed from each forging and submitted to physical tests to verify that each spar had been properly heat treated (Fig. 1).

As the spars were rough machined in the earlier way at the Division, excessive distortion was noted above and below the chord line (see sketch with Table I), accompanied by a closing of the hinge slot in the inboard attachment area. The closing of the hinge slot was caused by the removal of metal by machining and the accompanying partial relief of the residual stress induced during solution heat treatment. The distortion from the chord line was the result of the stresses relieved during rough machining of the *BCL* (basic contour line), milling of the hinge slot, and removal of the web cut. The distortion movement was so great—

in excess of 0.250 in.—that straightening of the part was required in order to maintain blueprint specifications. However, the difficult straightening opera-



tions not only produced cracks in the hinge slot radius but also frequently delayed production for several days.

Tests on the raw spar forgings by B.O.P. engineers disclosed that 7075 alloy was more difficult to control distortion-wise during machining than lower strength aluminum alloys, mainly because of its inherent high level of internal quenching stresses. Unfortunately, these stresses cannot be relieved by the usual stress relief treatments used on ferrous

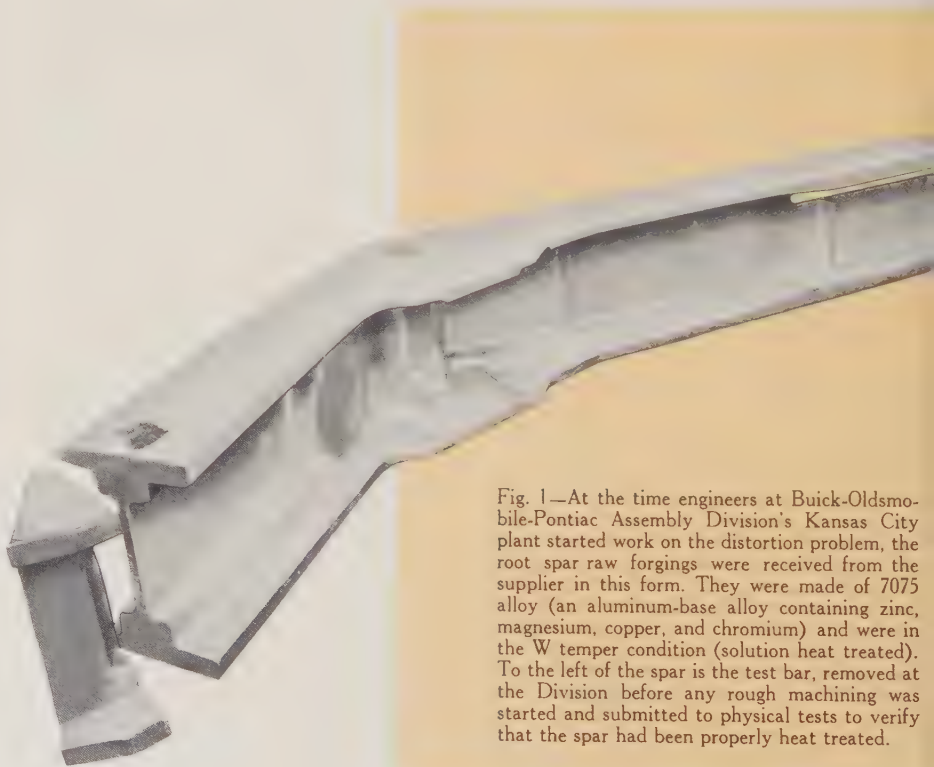


Fig. 1—At the time engineers at Buick-Oldsmobile-Pontiac Assembly Division's Kansas City plant started work on the distortion problem, the root spar raw forgings were received from the supplier in this form. They were made of 7075 alloy (an aluminum-base alloy containing zinc, magnesium, copper, and chromium) and were in the *W* temper condition (*solution heat treated*). To the left of the spar is the test bar, removed at the Division before any rough machining was started and submitted to physical tests to verify that the spar had been properly heat treated.

*For a glossary of terms see page 33.

Each successful experiment
produces something; adds to
present knowledge

alloys, as such treatments would ruin the effects of the aluminum alloy's previous heat treatment.

Several Proposed Solutions

When B.O.P. first set up the machining sequence for the spar forgings, the procedure was to clamp the forging tightly in the holding fixture, retaining the part in a straight position regardless of whether or not the forging or partially machined part was straight in the free condition. This followed the then-prevalent theory that the cutting operations on a forging held in this manner would relieve the internal residual stresses and, therefore, when the machined part was released from the holding fixture, it would lie in a straight plane. The first machining operations performed this way demonstrated the fallacy of this reasoning.

In another vein, several investigations were started to determine if machining the forgings in the *T6* temper condition (solution heat treated and artificially aged without cold working before aging) would show any improvement over machining forgings in the partially room-temperature aged or *W* condition. Supposedly, the artificial aging treatment at 250° F for 24 hr might lower the internal residual stresses in the part. However, tests proved that the aging cycle did little toward reducing these stresses.

Still another of the methods under consideration was to rework the forging dies to add metal to the critical areas of the spar forgings. However, this solution had two major disadvantages: it would cause a three-month delay in forging delivery and it would make obsolete

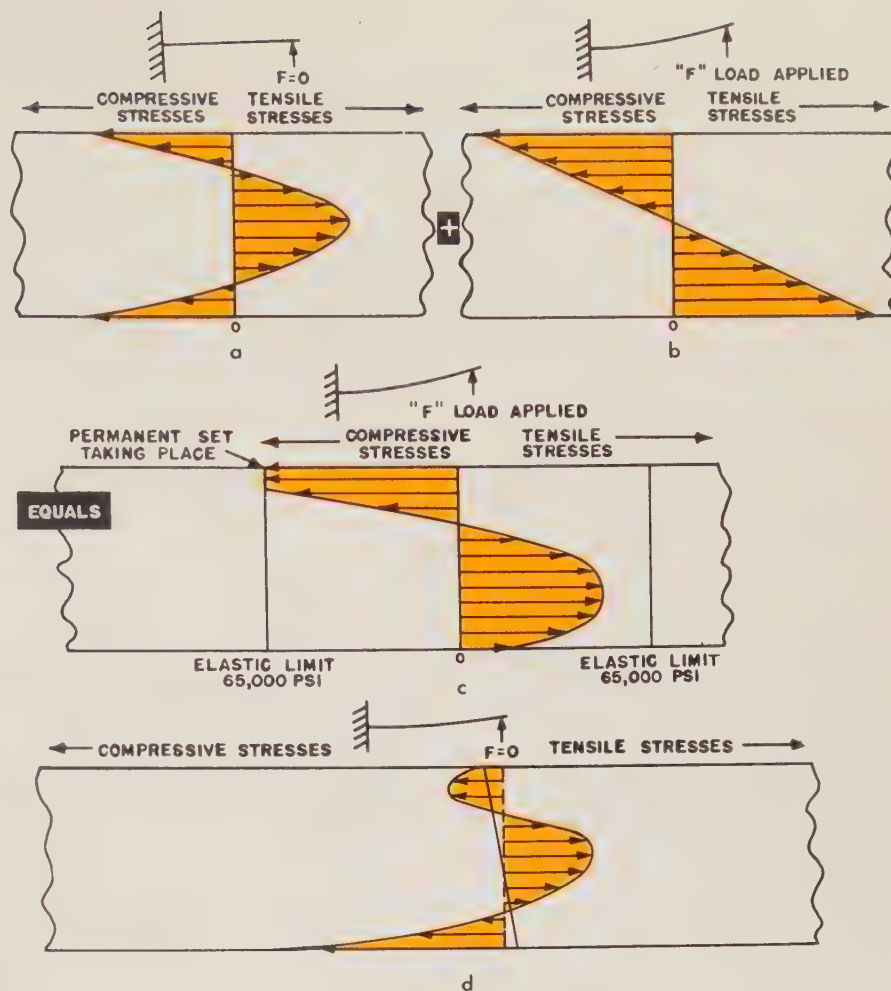


Fig. 2—One of the causes of distortion—redistribution of residual quenching stresses—is illustrated in this series of vector diagrams. Fig. 2a is a cross section of a forging after it has been quenched and cooled to room temperature. This forging is in the non-loaded condition and the tensile stresses in the core are equal to the compressive stresses in the skin. The forging in Fig. 2b contains no quenching stresses; however, the equal compressive and tensile stresses present are due to the light straightening load applied. Together, Figs. 2a and 2b equal Fig. 2c—cross section of a forging containing both quenching stresses and straightening load stresses. As the elastic limit in compressive stress is reached, the outer compressive vectors are limited to 65,000 psi. Fig. 2d is Fig. 2c without the straightening load and shows the resultant redistributed quenching stresses. The zero axis (shown by the dotted line) has shifted to the right and rotated to balance the opposing stresses. Because the upper compressive stresses exceeded the yield point under straightening load conditions, these same stresses now are reduced considerably under no load conditions. Hence, the unbalance of the compressive stresses in the two surfaces will cause the part to take on a permanent upward bend as indicated by the rotation.

some one-hundred sixty spars already on hand at the Division.

While none of these early experiments, of itself, solved the distortion problem, each contributed to the understanding of the causes and mechanisms of distortion in aluminum alloys and helped in the successful solution of the distortion problem.

Causes of Distortion in Aluminum Alloys

Combining information gleaned from a literature search and from the results of several preliminary experiments discussed

previously, B.O.P. engineers narrowed down the causes of distortion in aluminum-alloy forgings to four possible basic origins. These are:

- *Overheating during machining.* If sufficient cooling fluid is not used to prevent local temperature rises during machining operations, thermal expansion stresses may be induced in the part—stresses which are great enough to cause local yielding and permanent deformation.

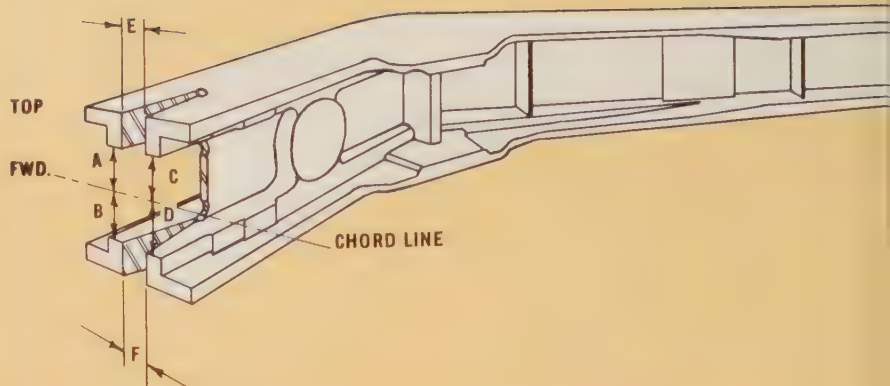
Aluminum alloys expand approximately twice as much with increasing

temperatures as does steel. This expansion sometimes causes misalignment or buckling of the part in the holding fixture. Consequently, if an overheated part is held in the fixture while further cuts are taken, after the part is released from the fixture and cooled to room temperature, it may have assumed a different configuration.

If an excess temperature build-up is allowed to occur during machining, it is remotely possible that *precipitation hardening* could cause a slight increase in the size of the part, resulting in some warpage. However, the warpage attributed to this cause is considered negligible. It is much more important to hold the temperature of the part below the precipitation hardening temperature range because of the fact that any uncontrolled temperature rise (usually above 325° F) could cause the part's physical properties to be lower than those specified. Consequently, it usually is the task of the Quality Control Department to insure that all aluminum forgings being machined are properly flooded with coolant.

At the time B.O.P. set up the sequence of operations for machining aluminum spars, carbon and high-speed steel cutters were used at low speeds—mainly as an economy measure. Later, experience demonstrated that carbide cutters—operating at 3,600 rpm, mounted on arbors 6 in. in diameter, with feeds of 50 in. per min having 1/4-in. deep cuts, and using a flood-water type of coolant—could be used with no detrimental effects from overheating or other undesirable conditions.

• *Redistribution or partial relief of residual quenching stresses.* The internal residual stresses, or quenching stresses, are first introduced into the aluminum forging during its initial solution heat treatment in the following manner. As the forging is first *quenched* from a temperature of above 800° F into a medium with a temperature below 200° F, the external surface or "skin" of the part undergoes rapid cooling. This reaction causes shrinkage of the outer skin surface; therefore, high tensile stresses are set up in the skin with compressive stresses in the core to balance the force system. As the part continues to cool, the core temperature diminishes until it has shrunk to the point at which the core stresses and skin stresses decrease to zero. As the part cools still more, the tensile stresses originally in the skin actually reverse and



Sectional View To Rough Machining of Original
1/4-in. Rivet Spars (inverted)

Processing Procedure	Part Serial Number	Movement In Excess Of Tolerance				Total Flange Spread	
		A	B	C	D	E	F
Test Bar Web Cut Out & Hinge Slot	117	—	0.052	—	—	0.213	0.228
	175	—	0.077	—	—	0.182	0.205
Test Bar & Slot Cut Only	122	0.069	0.080	0.042	—	0.183	0.205
	116	—	0.060	0.051	—	0.208	0.206
Slot Cut Only	138	0.095	0.073	0.030	—	0.238	0.225
	169	0.060	0.101	0.028	—	0.224	0.232

Table I—This table lists the distortion found after rough machining operations on the six experimental spar forgings. The two test spars with the test bar cut off, web cut, and the hinge slot cut out evidenced the least warpage. The small degree of straightening required by these forgings made them readily acceptable by the Quality Control Department. The other four spars needed some straightening but were accepted by this Department when finish machined.

become compressive, due to the continued shrinkage in the part's overall size. At room temperature, the part finally reaches a balanced condition of compressive stresses in the skin and tensile stresses in the core.

Consequently, when a machine cut removes an unequal amount of material from opposite sides of the part, the balance of tensile and compressive stresses within the part is upset to such an extent that the part is pulled into a warped condition. In order to restraighten the part, therefore, some of these stresses must be raised above the elastic limit by physically deforming the part so that, upon removal of the straightening load,

the stresses pulling the part into a warped condition will be reduced or redistributed.

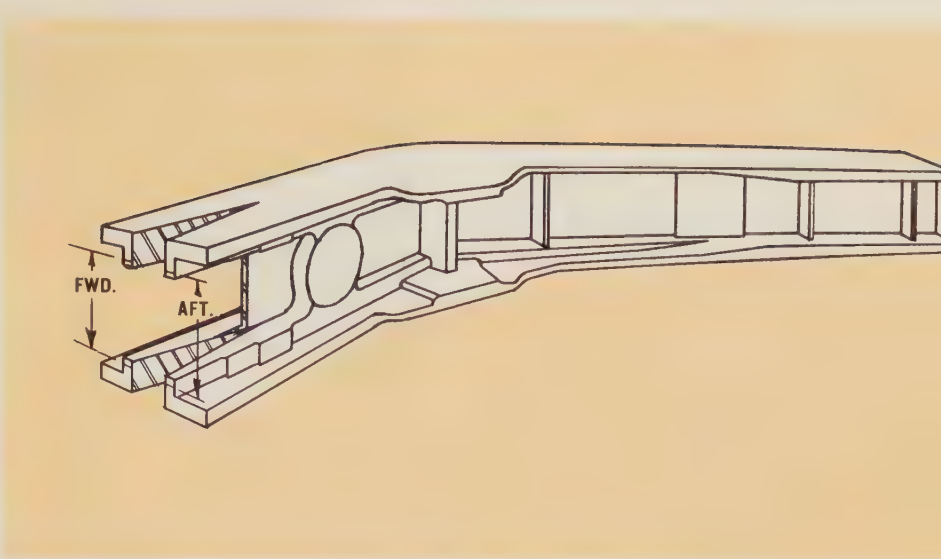
Straightening operations performed on unmachined forgings also cause a redistribution of the quenching stresses. If, during a straightening operation the forging is held in a cantilever, one surface of the part will be under tensile stresses and the opposite surface under compressive stresses. In order for any permanent set (permanent deformation) to take place, the elastic limit of the material must be exceeded in either the top, bottom, or both surfaces. Therefore, when the part is released from the straightening load, the surface area of the part in

which the compressive elastic limit was exceeded, may have a very low level of residual stress (Fig. 2). It is because of this phenomenon, then, that a part, after straightening, may show little or no distortion during the machining of that skin area which was previously under elastic compressive deformation during the straightening operation.

The magnitude of the residual stresses produced by solution heat treatment depends upon the heat treating temperature, the temperature and type of quenching medium, the size and shape of the part, and the composition of the alloy. A cold water quench induces higher stresses; whereas, a boiling water quench results in lower stresses. However, if the part is large in cross section, a cooler quench medium may be necessary to attain the required physical properties. Rough machining or forging recesses, slots, or other openings prior to solution heat treatment are beneficial because additional surface area per cubic inch of material is obtained; this results in additional heat dissipation during the quenching operation and, hence, in lower levels of residual stresses. Also, it has been proven that higher strength alloys exhibit higher stress levels upon quenching than do lower strength alloys.

• *Growth during age hardening.* While it was a generally accepted theory that an alloy's growth due to age hardening at room temperature or by artificial age hardening (250° F for 24 hr) would be sufficient to cause permanent distortion of machined parts, growth in an alloy is caused by an advanced stage of precipitation of an alloy's constituents and cannot occur at room temperature. In addition, carefully controlled artificial aging tests at 250° F for 24 hr showed no significant changes in dimension. Only by exposing the alloy to abnormally high temperatures, such as 350° F to 400° F, does the alloy exhibit any slight tendency to grow.

The proper support of long, thin spars with heavy masses concentrated at certain points was given preliminary attention to prevent permanent set taking place while at elevated aging temperatures because of the spar's own weight. However, apprehensions about this potential trouble spot soon were proven unwarranted. Consequently, at B.O.P. the distortion attributed to growth during the aging process was considered a



Dimensional Change During Machining of Ten Additional Spars (inches)

Spar Serial No.	Orig. Dim. Solution Heat Treat Fwd. & Aft	After BCL Cut (Hydrotel)		After Rough Hinge Slot		After Finished Hinge Slot		Nominal Finish Dimension Fwd. & Aft
		Fwd.	Aft	Fwd.	Aft	Fwd.	Aft	
195L	7.000	7.109	7.062	7.125	7.125	7.140	7.125	7.160
196L	6.968	7.078	7.093	7.093	7.093	7.093	7.093	7.160
197L	7.000	7.062	7.062	7.093	7.093	7.093	7.062	7.160
198L	6.937	7.046	6.937	7.062	7.062	7.093	7.093	7.160
200L	6.968	7.031	7.062	7.031	7.125	7.031	7.125	7.160
201L	6.937	6.968	6.953	7.000	7.031	7.031	7.062	7.160
202L	7.062	7.093	7.093	7.156	7.093	7.156	7.109	7.160
203L	6.968	7.000	7.062	7.062	7.062	7.093	7.062	7.160
204L	7.000	7.109	7.125	7.125	7.093	7.125	7.125	7.160
205L	6.937	7.031	7.047	7.062	7.125	7.093	7.125	7.160

Table II—After processing of the six experimental spars, 10 additional follow-up spars were tested to corroborate data from the six original spars. The 10 spars were prepared by removing the test bar and completing the web and hinge slot cuts—using a method that could be duplicated by the supplier. After re-solution heat treatment and straightening by the supplier, a dimensional check after rough machining showed that straightening was not required on any of the 10 spars before installation of the hinge. This table shows that the movement of the spars during the complete processing sequence was negligible.

negligible factor.

• *Overloading by clamping too tightly in the holding fixture.* Machine operators accustomed to machining steels sometimes have a tendency to clamp aluminum parts too tightly in the holding fixture, disregarding aluminum's lower modulus of elasticity. If the fixture's support buttons are not directly under the

clamps, there is a possibility that the part will be deformed and stressed beyond its yield strength. If the temperature of the part rises during machining operations, its yield strength is further weakened. In addition, because of the high expansion of aluminum during elevated temperatures (almost twice that of steel), further strains are imposed on the part

if it is clamped too tightly in the holding fixture. Consequently, there is some degree of distortion during further machining and after removal of the part from the holding fixture.

Each of the four causes of distortion just discussed was taken into consideration during the final successful solution of the distortion problem.

Successful Solution of Distortion Problem

After the several preliminary experiments, it was decided to approach the distortion problem from the aspect of determining the best manner of reducing and/or inducing a different pattern of quenching stresses throughout the hinge slot area.

Experimental Processing of Spars

With this objective in mind, six left-hand spar forgings were assigned to the B.O.P. Machine Shop as experimental parts to be processed following the Division's process sheets so that the finished forgings would meet Divisional specifications. The six spars were divided into three categories (a) test bar cut off, web cut out, and hinge slot cut out, (b) test bar cut off and web cut out, and (c) hinge slot only cut out. These cuts were made on each of the spars using simple machine tool equipment, in order to simulate an actual production sequence at the forging suppliers' plants where there might be no machine shop facilities available.

The prepared spars were returned to the supplier for re-solution heat treatment and straightening. They were heat treated in pairs in a Swindel Extrusion Furnace; the heat treating cycle consisted of 1 hr to heat the forgings uniformly to 870° F and a 1 hr soaking period at this temperature.

The spars were quenched in water at 180° F and immediately transferred to the presses to be straightened within 1 hr. (From the supplier's past experience, any straightening done beyond 1 hr after removal from the quench tanks increases the possibility of fracture.)

Next, the spars were returned to B.O.P. for processing and were machined in the following manner, on the inboard end only to expedite the processing:

- (1) Machine holes and spot faces on forward side
- (2) Rough mill aft side of web
- (3) Mill slot through web to form finish edge of web

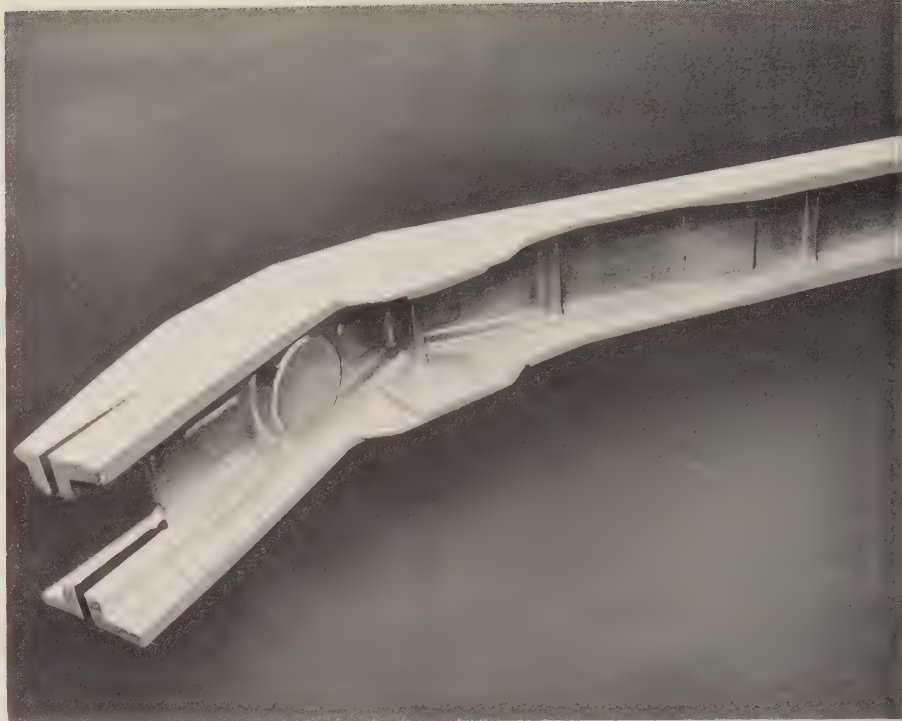


Fig. 3—Experimental processing of the root spar raw forgings by B.O.P. engineers showed that the quenching stress in the spar's hinge slot area could be reduced by providing a greater surface area of contact for the cooling medium. Consequently, after the successful experimental work, spars were received from the supplier with the web cut and with the rough hinge slot cut in. In contrast, Fig. 1 is an illustration of a forging as they were supplied to B.O.P. prior to work on the distortion problem.

- (4) Finish mill inboard edge of two bottom flanges
- (5) Rough contour mill top of inboard leg
- (6) Rough contour mill bottom of inboard leg
- (7) Rough mill tapered slot in top for hinge fitting
- (8) Rough mill tapered slot in bottom for hinge fitting.

After the rough milling operations on the BCL surfaces and the hinge slot were completed, the spars were checked dimensionally at the innermost inboard end of the spar, at the tips of the four legs, for the distance from the chord line to the bolt step (Table I, top).

Results

The two spars with the test bar cut off, web cut out, and the hinge slot cut out evidenced the least warpage (Table I, top). The small degree of straightening required for these forgings made them acceptable.

The other four (two with test bar cut off and web cut out and two with hinge

slot only cut out) needed some straightening but were accepted by the Quality Control Department when finish machined. Table I lists the amount of distortion found after rough machining of the six root spar forgings.

Further Tests

To substantiate the data obtained from the six test spars, 10 additional spars (five left hand and five right hand) were prepared by removing the test bars and completing the web and the hinge slot cuts, again using a method that could be duplicated by the supplier. Then the spars were returned to the supplier for re-solution heat treatment and straightening.

Because of the behavior of the six original spars, it was felt that over-straightening of the inboard section would eliminate completely any necessity for straightening during rough machining. Consequently, while the same heat treat and straightening procedures were followed as were used on the original six, with the 10 follow-up spars the BCL was distorted 0.060 in. to 0.100 in. below nominal toward the chord line

and the hinge slot was spread 0.040 in. in excess of the nominal from the centerline. The spars were returned to B.O.P. for machining, following the same operations as were used with the original six spars.

After rough machining, the spars were checked dimensionally at the same points as the original six experimental spars which showed that straightening was not required on any of the 10 parts before installation of the hinge.

Since there remained the possibility of additional distortion occurring during finish milling of the hinge slot, the spars were observed throughout the complete processing sequence and the movement recorded was negligible (Table II).

Test Results and the Supplier

Because these experiments showed that for maximum relief of stress the spars should be specially saw cut by the supplier after forging and prior to solution heat treatment, B.O.P. furnished the supplier with the adequate fixtures needed to produce spars to the new specifications.

The first fixture, developed by B.O.P.'s Tool Design Group, was used for locating and drilling saw relief holes through the flanges, prior to sawing of the hinge slot.

An additional fixture was constructed for sectioning the test bar and rough sawing the web cut.

B.O.P.'s Development Laboratory engineers acted in a further advisory capacity for the supplier in setting up production and in establishing quality control receiving standards.

Summary

These experimental programs aimed at reducing distortion in aluminum-alloy forgings led to several workable solutions and to valuable conclusions. Some outstanding results were:

- The reduction of stress in the hinge slot area due to quenching was accomplished by providing a greater area of contact for the cooling medium. Removal of the test bar end, the web cut, and rough cutting the hinge slot accomplished this by providing a maximum of contact area for quenching the inboard section of the root spar forging. In contrast with Fig. 1 which shows the forging as it was supplied prior to these tests, Fig. 3 is an illustration of a root spar forging as they were subsequently re-

ceived from the supplier with the web cut and the hinge slot cuts roughed in.

- Less distortion resulted from machining operations on these later spars because of the reduction of the normally high stress level and because of a different pattern of induced quenching stresses, particularly in areas of large cross section.

- Difficult straightening operations and accompanying cracks have been eliminated. Previously, straightening each spar required 4 hr to 8 hr, excluding the time required for the removal of cracks and for *Zygo inspection*. Production time lost had ranged from one to two days.

- The time required for machining the hinge slot was reduced and the complexity of the machining operation re-

Glossary

For paper beginning on page 28: "Causes and Control of Distortion during Machining of Aluminum-Alloy Forgings."

BCL refers to the basic contour line of an airfoil. It is a line which designates the finished aerodynamic surface of an airfoil as shown by any cross section. The upper and lower faces of the root spar referred to in the attached paper are exposed surfaces and form a part of the wing surface after assembly of the spar into a finished wing structure. Therefore, any surface of the spar which constitutes a portion of the finished wing airfoil surface is referred to as the BCL.

Chord line is a line representing the intersection of the chord plane with the web section of a spar. The *chord plane* is a basic reference plane erected horizontally and which intersects the spar at the midpoint of the web; it is a datum plane erected only for the convenience of the designer for easy dimensioning of the spar.

Hydrotel is a milling machine

which utilizes a tracer and model pattern for contouring work in either two or three planes, using electrical and hydraulic means for controlling the movements of the tracer and mill cutting heads.

Solution heat treatment is a strengthening thermal treatment applicable to the heat-treatable aluminum alloys in which the metal is heated to a suitable temperature, held at this temperature long enough to allow certain alloy constituents to enter into solid solution, and then is cooled rapidly to hold these constituents in solution. *Quenching* is a method of suddenly cooling a metal at high temperatures by immersion in a medium of lower temperatures, for example, water, air, or ice.

Zygo inspection is a testing method used to discover cracks in nonmagnetic metals. The cracks are located by the use of fluorescent powder and black light.

lied because there was less opportunity for machining errors due to distortion.

- For maximum relief from stress, the special slots were rough cut by the supplier, after the forging operation and prior to solution heat treatment. This eliminated milling operations at B.O.P.

- The reduction of distortion and the elimination of straightening operations on the spar forgings resulted in a substantial financial saving on each spar.

Acknowledgement

Messrs. Thomas and Gilliland wish to express appreciation for material obtained from the Aluminum Company of America and used in the preparation of this paper.

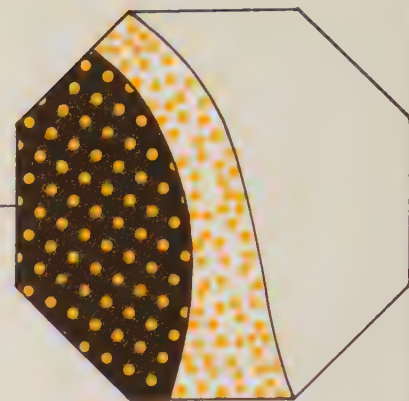
Investigation of Barrel Finishing as a Means of Efficient Burr Removal

Increasing production rates on precision parts have generated the problem of removing safely any burrs or sharp edges from production parts before they can be plated or assembled. Industry demanded that this burr removal be fast and that it be economical. Barrel finishing, developed during World War II, seems to be the answer. Because of its larger number of production parts necessitating burr removal, the Transmissions Operations Group of Allison Division initiated a laboratory study of the four popular methods of barrel finishing to determine this process' economics and potentialities for parts then in production. The study resulted in a set of procedures to follow in order to make the barrel finishing process work successfully and produce like results time after time.

THE removal of burrs is a necessary operation in the fabrication of any precision product. In the past, burring was expensive because this operation was performed largely by hand burring methods. Present-day production requirements, however, make it necessary to reduce the time, as well as the cost, required for a particular operation. In striving to meet this challenge, several different mechanical methods of burr

removal have been developed. One of the most economical methods, in most instances, is the use of the barrel finishing process.

Recently, a study of the barrel finishing process was conducted by the Transmissions Operations Group of Allison Division to determine the economics and potentialities of this method of burr removal for parts then in production. In addition, this study was to serve as a



guide in planning future production projects. In all, the study covered barrel speeds, cleaning compounds, types of media, and the four most widely used methods of barrel finishing.

Barrel Finishing Principles

Barrel finishing is a process in which a definite quantity of parts is placed in an enclosed barrel along with water, a cleaning compound, and a medium. (In barrel finishing terminology, *medium* refers to the material used to remove the burrs.) The barrel is rotated at a predetermined speed for a definite interval of time. While the shape of the barrel may

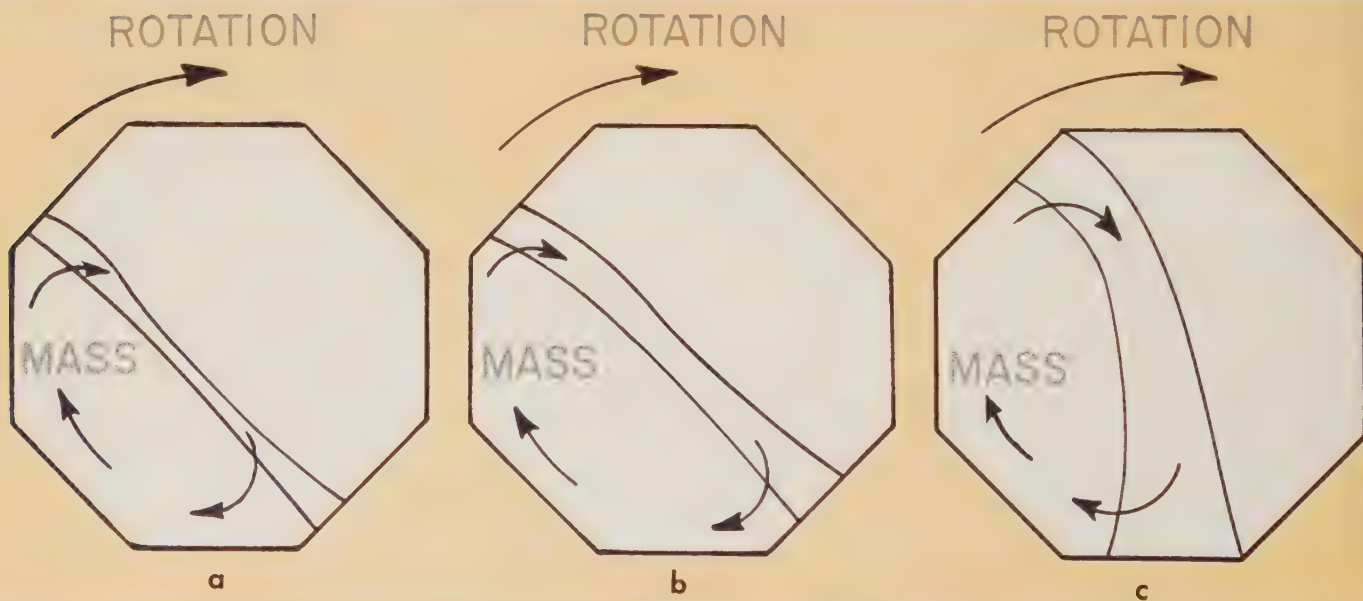


Fig. 1—During barrel finishing, as the barrel rotates its flat sides lift the contents to a point at which they begin to slide to the opposite side. In this sliding action, the medium grinds the parts, removing the burrs. Barrel speed is an important factor because if the barrel is revolving too slowly the effective sliding area is at a minimum and the parts will not slide from one side of the barrel to the other. Consequently, there is no burring action. Too fast a barrel speed causes the parts to be carried beyond the point where the effective slide begins, allowing the parts to drop from one side of the barrel

to the other and resulting in damaged parts. In Fig. 1a, an end-view drawing of an octagonal-shaped barrel rotating at 10 rpm, the effective sliding area is between the two lines. The arrows indicate the path followed by the parts during rotation. In Fig. 1b the barrel is rotating at 20 rpm and the effective sliding area has increased in thickness. In the last view (Fig. 1c), with the barrel rotating at 30 rpm, the effective sliding layer is much steeper and wider than for the slower speeds.

Results of laboratory
studies produce improved
barrel finishing techniques

vary, for burr removal purposes an octagonal-shaped barrel is preferred because the flat sides tend to speed up the process. As the barrel rotates, the flat sides lift the mass to a point at which it tends to slide to the opposite side of the barrel. (*Mass* includes the entire contents of the barrel—medium, parts, and solution.) During this slide, the parts are subjected to a grinding and/or polishing action by the sliding medium—grinding action if burr removal is desired, burnishing if surface finish improvement is desired. It is this sliding action which causes the burrs to be removed. The application of this process to improvement of the root mean square (RMS) surface finish depends upon the selection of cleaning compounds to be used. However, this paper deals primarily with burr removal rather than with improvement of surface finish.

Barrel Speed

The Allison investigation showed that too slow a barrel speed produces an excessively long cycle because the length of the effective slide is at a minimum in width and length. On the other hand, too fast a barrel speed causes the parts to be lifted beyond that point at which the effective slide begins. When this happens, the parts drop from one side of the barrel to the other and no burring action occurs. Rather, the parts are damaged by hitting each other as they fall. Fig. 1 shows the sliding action which occurs at various barrel speeds.

Cleaning Compounds

Various tests were conducted to prove the need for cleaning compounds in barrel finishing. It can be stated without reservation that some type of a cleaning

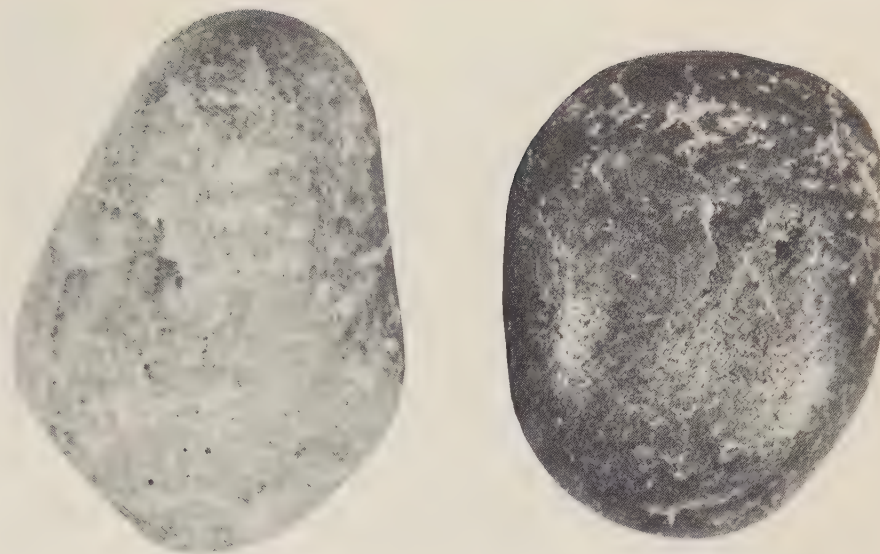


Fig. 2—As the medium and the parts slide past each other in the barrel finishing process, the medium acts much the same as a grinding wheel, removing small particles of metal from the parts. Consequently, to be effective, the medium must maintain clean, sharp cutting edges. This illustration shows an example of both clean and glazed-over media. The clean medium on the left kept its cutting action because the correct amount of cleaning compound was used during the process; cleaning compounds tend to keep the fine metallic particles in suspension in the solution so they cannot adhere to the medium. The dark appearance of the medium on the right was caused by fine particles of aluminum which were removed from parts during barrel finishing. These aluminum particles which deposited on the medium caused it to glaze over and lose its value for burr removal. However, processing this medium with a sufficient amount of cleaning compound removed all the metallic build-up.

compound should be utilized whenever the wet barrel finishing process is used. (*Wet barrel finishing* is the term applied whenever any liquid is used in the barrel during the process.)

Cleaning compounds serve two primary functions in this process. First, they tend to remove the oils and greases left on the parts from previous machining operations, allowing the sliding medium to make direct contact with the burr which is to be removed. If the oils and greases are allowed to remain on the parts during the process, they act as lubricants between the parts and the medium, and little or no burr removal is accomplished during the slide.

Secondly, cleaning compounds tend to keep the medium clean and free from metallic build-up. As the medium and parts slide past each other during the process, the medium acts much the same as a small grinding wheel, removing small particles of metal from the parts. If these fine particles of metal are not kept in suspension in the solution they adhere to the medium and cause it to glaze over (Fig. 2). Very little grinding action can be secured by using a glazed-over medium. As the cleaning compounds tend to keep the fine metallic particles in

suspension in the solution, these particles can be removed easily from the barrel at the end of the cycle simply by emptying the solution.

Types of Media

There are three basic types of media: natural (for example, limestone and granite), aluminum oxide which is manufactured, and various steel shapes.

The natural type of medium can be used economically for burr removal provided it is used in conjunction with some type of an abrasive compound. The principal disadvantage of the natural type of medium is its slow rate of burr removal due to its slow rate of breakdown. Therefore, if speed of burr removal is desired, an aluminum oxide medium or some form of steel shapes should be used because these media have a greater rate of breakdown than natural media, thus more sharp cutting edges are exposed. These many minute sharp edges cut the burrs during the slide. During the investigation conducted at Allison, on one part where the medium was changed from a natural type to an aluminum-oxide type, the cycle time was reduced 66 per cent.

Excellent results can be secured with

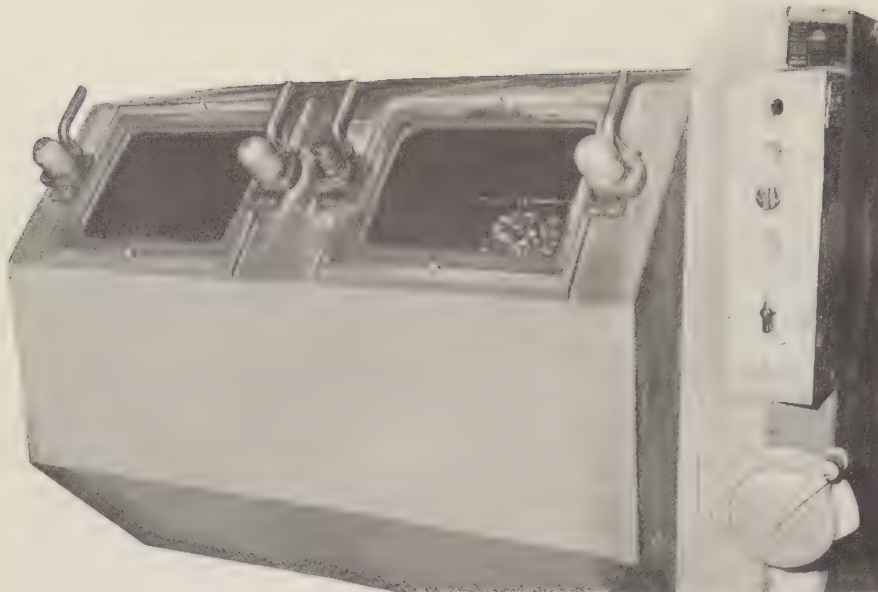


Fig. 3—This is an illustration of the equipment used in one of the four methods of barrel finishing investigated at Allison Division. This two-compartment barrel is used for processing parts in the loose state—the most widely used industrial method. The parts and medium are placed in the barrel and processed for a definite interval of time at a definite barrel speed. (The time and speed are determined after several experimental runs.) The Allison investigation disclosed that the best results were secured when the barrel was loaded 50 per cent to 60 per cent full of medium and from 15 per cent to 20 per cent full of parts. The total mass should not be more than 75 per cent of the capacity of the barrel in order to secure the maximum slide.

steel shapes only if they are used in conjunction with an abrasive compound. The shapes may be used in the soft state or they may be heat treated for increased hardness. When steel shapes are used with an abrasive type of compound, they tend to become embedded with fine abrasive particles of the compound. This makes each shape act as a tiny lap. As the individual steel shapes generally

are heavier than any other type of medium, they exert more force against the part during the slide. As a result, the burr removal process is greatly speeded up.

When selecting any type of medium to use, its size should be large enough to prevent it from lodging in the part yet small enough to pass through any hole in the part. For maximum speed of burr



Fig. 4—The brackets in this illustration are used on the Allison CD 850 transmission and are examples of parts processed in the loose state. Those parts processed in this particular manner must be unloaded carefully at the end of the barrel finishing cycle to prevent possible damage to the parts when the barrel is emptied. When loose processing was used at Allison Division, a wire basket was clamped to the door of the barrel at the end of the cycle and the parts and medium slid into the basket. Because the mesh of the basket was large enough to allow the medium to pass through but small enough to hold back the parts, the two were separated quickly without involving any hand separation. During the Allison investigation, 60 of these brackets were processed per load in a 36-in. diameter, two-compartment barrel for a period of 1 hr at 10 rpm. The medium used was of the grinding type and the cleaning compound was soda ash. At the end of the cycle, no additional burring was required. (This wire basket method of unloading was used for parts weighing approximately two or more pounds; for smaller parts another method, described in Fig. 5 caption, was devised.)

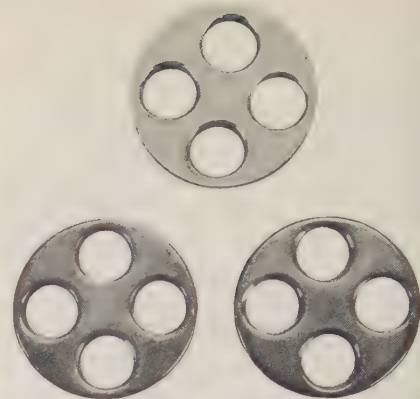


Fig. 5—When the loose processing method of barrel finishing is used, special care must be exercised when loading and unloading the barrel. One of the methods of unloading—employed by Allison Division for those parts weighing only a few ounces—involved transferring the mass from the barrel into chip pans and placing the pans on a mechanical separator. This separator—it may be either magnetic or hand-operated—allowed the mass to flow onto a screen which kept the parts on the top while the medium fell through the screen. The brass bearing races in this illustration were unloaded in this manner after being processed, several thousand at a time, in a 36-in. diameter barrel for 4 hr. The primary objective in processing this part was to secure a certain radius around the edge of the part; burr removal was secondary. After processing, the radius on the two parts in the lower portion of the illustration is approximately fifteen thousandths of an inch. Note the sharp edge on the bearing race in the upper portion of the illustration. Allison studies showed that use of the loose processing method of barrel finishing and this method of unloading instead of hand finishing and hand separating speeded up the process approximately five hundred per cent.

removal the smaller sizes of media generally are not used, due to their relatively light weight. For the most part, the larger the size of the medium which can be used, the faster the rate of burr removal. However, too large a medium will cause the edges of the part to be rolled or peened over during the barrel finishing process.

Types of Barrel Finishing Processes Used in Allison Investigation

Four different methods of barrel finishing were considered during this investigation. These were: the processing of parts in the loose state, use of multiple compartment barrels, use of arbors and/or fixtures, and the self-processing of parts.

Processing in Loose State

The most widely used method was the processing of parts in the loose state. This method consisted of placing several parts in the barrel along with the medium and processing for a definite interval of

time at a definite barrel speed (Fig. 3). Best results were secured when the barrel was loaded 50 per cent to 60 per cent full of medium and from 15 per cent to 20 per cent full of parts. The total mass should not be more than 75 per cent of the capacity of the barrel to secure a maximum amount of slide.

Care must be exercised during loading and unloading of the parts from the barrel when this method of finishing is used. For loading, best results were secured when a portion of the parts was placed in the barrel and jogged back and forth several times. This allowed the parts to bury themselves in the medium before all parts were loaded and, therefore, nicking of the parts was eliminated. At the end of the barrel finishing cycle care had to be exercised when dumping the mass to prevent the parts from being damaged. This was overcome by using a wire basket which clamped to the door of the barrel. The parts and medium were allowed to slide into the basket. As the mesh of the wire basket was large enough to allow the medium alone to pass through, the parts were readily removed from the basket with no hand separation required. This method of unloading was used on parts weighing approximately two or more pounds.

In the case of smaller parts weighing only a few ounces another method was used. The mass was dumped into chip pans and placed on a mechanical separator. This separator—which may be either magnetic or hand-operated—allowed the parts to flow onto a screen which kept the parts on top while allowing the medium to fall through.

An example of parts processed using the wire basket method of unloading the barrel is the brackets shown in Fig. 4. Sixty of these brackets were processed per load in a 36-in. diameter, two-compartment barrel for a period of 1 hr at 10 rpm. The medium used was a grinding type and the cleaning compound was soda ash. At the end of the 1-hr cycle the parts were removed from the barrel and sent to final inspection with no additional burring required.

Brass bearing cages (Fig. 5) represent parts which were removed from the barrel by dumping the mass into chip pans and using a mechanical separator. The primary objective on this part was to secure a radius around the edge of the part with burr removal being secondary. Due to the size of this part, $\frac{3}{8}$ in.

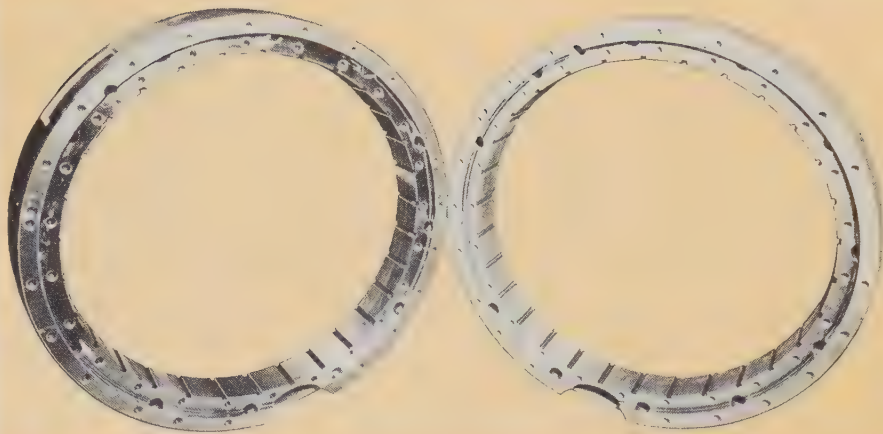


Fig. 6—The multiple compartment method of barrel finishing is used on parts having a regular or a smooth peripheral surface. In most cases, these parts are too large to go through the barrel-door openings on the machines used for loose processing or they are too heavy for this method of barrel finishing. The brake anchors shown in this illustration were processed by the multiple compartment method; they are 22 in. in diameter by 4 in. wide and weigh $40\frac{1}{4}$ lb each.

in diameter and $\frac{1}{2}$ in. thick, it was difficult to hold by hand and form the desired radius. These parts were processed several thousand at a time in a 36-in. diameter barrel for a period of 4 hr. At the end of this time, the radius secured was approximately fifteen thousandths of an inch. While no exact cost figures were obtained for this part, the process was speeded up approximately five hundred per cent.

After the parts were removed from the barrel and placed in tote pans, they were dipped in a soluble oil and water solution to prevent the formation of rust. This solution tended to keep the parts oily and, therefore, prevented the medium breakdown from drying on the parts. Since there were subsequent operations, such as tapping, to be performed on the parts prior to final inspection, the oil and water coating made it easier to wash the parts.

Multiple Compartment Barrels

The multiple compartment method of barrel finishing was used on parts having a regular or a smooth peripheral surface. These parts were generally too large to go through the door opening on machines used for loose processing of parts or their weight was too great for the loose processing method.

This type of barrel finishing, while adding to the versatility of the process in general, has some disadvantages. The medium breakdown is much greater in a multiple compartment barrel than in one

used for loose processing. This is due to the restricted movement of the parts which must remain in one plane during the process. In this type of barrel the parts tend to do more rolling than sliding as the barrel rotates. As the parts roll they tend to trap the medium against the flat sides of the barrel and fracture it.

Brake anchors (Fig. 6) were processed by the multiple compartment barrel method. The width of each of the compartments in the barrel was approximately six inches; the parts were 4 in. wide (Fig. 7). This left very little room for the medium to work around the part as it was being processed. A very slow barrel speed was the only way that the breakdown of the medium could be retarded.

When the multiple compartment method of barrel finishing was used on these parts there was a 50 per cent savings realized.

Use of Arbors and/or Fixtures

Arbors and/or fixtures were used on parts having an irregular peripheral surface. Due to the projections on the peripheral surface, it was not advisable to process this type of part in a multiple compartment barrel. The projections would have damaged the barrel lining, as well as damaging the parts. By using arbors and fixtures, damage to the lining and parts was eliminated.

One of the best applications of this method of processing parts was on the end plates used on the CD 500 transmis-



Fig. 7—The brake anchors shown in Fig. 6 were processed in this multiple compartment type of barrel. The parts are 4 in. wide while each compartment is only 6 in. wide. Consequently, there is very little room for the medium to work around the part as the barrel rotates. Also, the parts tend to roll more than slide, trapping the medium against the sides of the compartment and fracturing it; this is one disadvantage to this method of barrel finishing. However, breakdown of the medium can be retarded by rotating the barrel very slowly. Allison Division's records show that by using the multiple compartment barrel, savings were as high as 50 per cent.

sion (Fig. 8). These parts were processed 14 per load for 30 min at approximately twenty revolutions per minute. A keyed hub was placed in the center of each part and fastened in place by three bolts. This assembly was placed on an arbor. The arbor and parts were loaded in the barrel and secured in place by a hinged collar which was fastened to the end plates of the barrel. A positive drive was secured by means of a pin in the stationary half of the split collar. This pin projected into a slot in the end of the arbor (Fig. 9).

Due to the shape of this part, some hand burring was required after the barrel finishing operation. However, the total time required to burr these parts completely by hand was reduced by approximately sixty-five per cent when the barrel finishing process was used.

The one chief disadvantage of this type of barrel finishing is the amount of time required to load the parts on the fixtures and the arbors. However,

due to the large number of end plates which could be processed per load by this method, this factor was not objectionable.

Self-processing

The self-processing method was used on small punch press parts where finish was of no importance. This method eliminated the separating of parts from the medium at the end of the barrel finishing cycle. In some instances, the parts were smaller than the medium which could have been used to process them. This would have made a magnetic separator necessary for separating parts from the medium. However, production schedules were not sufficient to make the magnetic type of separator economically feasible. Thus, to eliminate the separation problem, small parts such as washers and small plates were processed using no medium at all. Such parts were processed in a 16-in. diameter barrel using only water and a fine abrasive powder. (A larger diameter barrel would have been used had production schedules justified.) The abrasive powder was used to break the surface tension which caused the parts to stick to the sides of the barrel, as well as to each other. In addition, this abrasive speeded up the process to a small degree.

Parts processed by this method generally were scratched and nicked but, as previously stated, finish was not the prime requisite.

Recommended Procedure

The Allison study pointed out several procedures which should be followed if the barrel finishing process is to work successfully and produce like results time after time. These are:

- (1) Keep the barrel at least one-half full of medium at all times during the processing cycle. This tends to prevent the barrel lining, as well as the parts, from being damaged.
- (2) For fast cutting of burrs keep the water level low.
- (3) Use only enough cleaning compound to keep the parts and medium clean. Too much compound produces an excess of suds which tends to retard the medium's cutting action because the suds act as a cushion.
- (4) After a particular part has been processed for the first time make a record of the type of machine used, the number of parts per work load, the size and type of medium used, the length of time,



Fig. 8—Another method of barrel finishing—use of arbors and/or fixtures—is employed for parts having an irregular peripheral surface. This type of part cannot be processed in a multiple compartment barrel because any surface projections might damage the barrel lining or strike other parts. The transmission end plates shown in this illustration are necessarily processed using arbors and fixtures. The fixture fits in the center of the part; then the part and the fixture are mounted on an arbor.

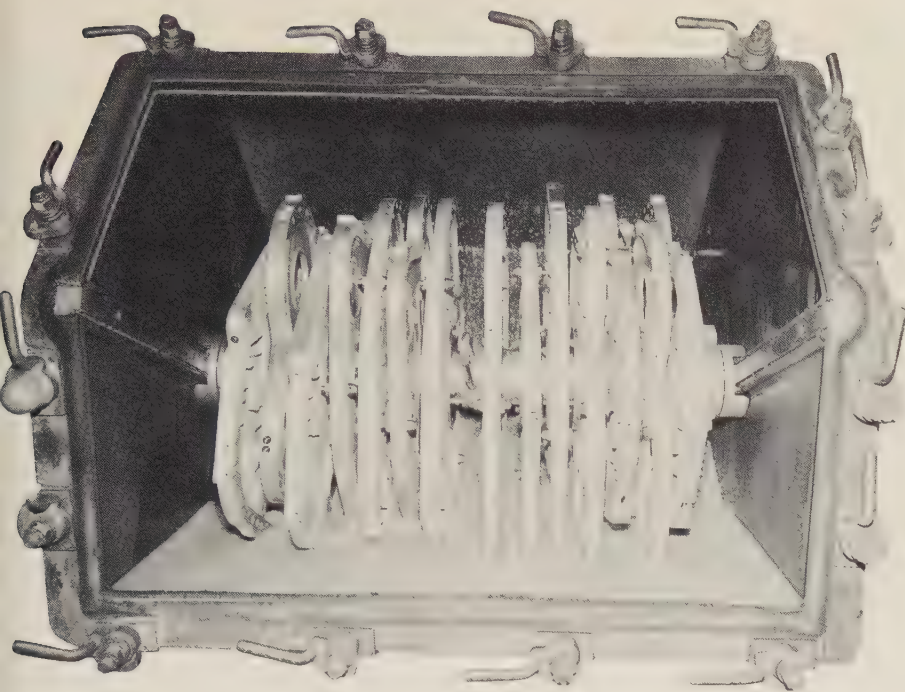


Fig. 9—The transmission end plates shown in Fig. 8 are processed 14 per load in a 48-in. diameter barrel using a 30-min cycle at approximately twenty revolutions per minute. A keyed hub was placed in the center of each part and then fastened in place by three bolts; this assembly was placed on an arbor. The parts and arbor were loaded in the barrel and secured by a hinged collar fastened to the end plates of the barrel. Because of the intricate shape of the part, some hand burring was required. However, the hand labor was reduced approximately sixty-five per cent when barrel finishing was used.

and the number of revolutions per minute of the barrel used to process the part. If the results secured on the initial attempt are acceptable to all concerned, this record should become the permanent record for processing. Should it be necessary to process the part two or three times to secure acceptable results, a record of each run will prevent any duplication of effort.

- (5) When processing ferrous parts for the first time a three to one ratio of medium to parts by weight is a good rule to use. In some instances, finish requirements may make it necessary to use a ratio as high as six parts of medium to one part of parts by weight.
- (6) On aluminum parts the ratio of parts to medium should be determined by the size of the individual part, rather than by weight.

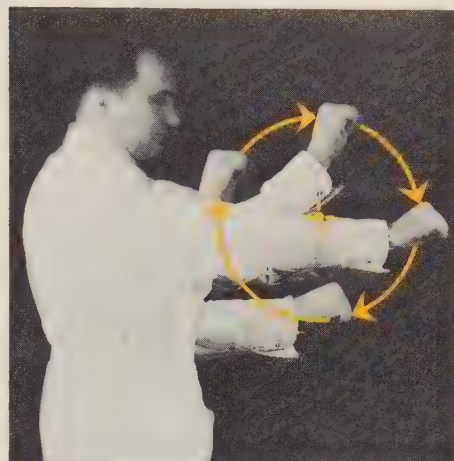
Maximum utilization of this process can be secured only on volume production of parts. This eliminates changing the medium from one run to the next which is time-consuming and costly.

Summary

There are several distinct advantages which may be secured by using the barrel finishing process in place of the hand burring method. However, this process should not be considered a solution for all burring problems. Some types of parts, due to their size and shape, do not adapt themselves to this process. The advantages of barrel finishing are:

- Barrel finishing will produce a more uniform overall finish on a part than can be produced by the hand burring method. This is due to the fact that the whole part is submerged in the medium and is subjected to the medium's action on all surfaces.
- Barrel finishing generally is less expensive than hand burring because less direct labor is involved.
- The barrel finishing process generally is much faster than the hand burring process.
- The barrel finishing process will produce like results time after time if the process is used properly.

Correction



Richard R. Farley, Process Development Section author of "Some Principles of Methods and Motion Study as Used in Development Work" which appeared in the November-December 1955 issue of the GENERAL MOTORS ENGINEERING JOURNAL, has called attention to incorrect editorial identification for the rotary motions shown in Fig. 5, page 24. The caption for Fig. 5, as printed, identified the photograph on the right as depicting incorrect rotary motion. This, however, was not the case.

The rotary motion depicted by the figure at the top, originally identified as incorrect motion, shows correct rotary motion based on the design concept that rotary motion should have its rotational axis perpendicular to a line drawn from the center of the rotary motion to the shoulder pivot point. The figure at the bottom, originally identified as correct motion, depicts incorrect rotary motion because the rotational axis of the motion is parallel to a line drawn from the center of rotation to the shoulder pivot point.



An Improved Method for the Economic Reconditioning of Aircraft Spark Plugs

The reconditioning of an aircraft spark plug is based on a series of individual operations, each of which contributes to provide a spark plug which will be functionally acceptable for reuse in the aircraft's ignition system. Each operation requires an individual and specialized piece of equipment. Usually, the equipment is located in such a manner that much time is lost in transferring a plug from one operation to another. When many plugs have to be reconditioned, as in the case of commercial airlines, the economic aspects of the reconditioning procedure take on considerable importance. AC Spark Plug Division's engineers, in an effort to improve and to instill economy into the procedures used for aircraft spark plug reconditioning, recently designed and built a unit called a Servicing Facility which concentrates all equipment required for reconditioning on a convenient bench. Also, new equipment and fixtures were designed to provide maximum ease, safety, accuracy, and the least danger of damage to the plugs while being processed through the Facility.

THE severe heat stress and wear resulting from extreme temperatures and pressures generated within the combustion chamber of an aircraft engine require that spark plugs be reconditioned after established periods of operation to insure that proper ignition, so vital to the safe performance of aircraft, will be maintained.

When plugs are removed from an engine they are examined thoroughly and, if found in suitable condition, are put through a reconditioning process which consists of several individual operations performed by trained personnel using specialized tools and equipment usually mounted on individual stands,

with the plugs carried from one operation to another in trays.

AC Spark Plug Division's engineers, recognizing the need for improving aircraft spark plug reconditioning practices, recently designed and built a unit known as a Servicing Facility to be used for reconditioning commercial aircraft spark plugs (Fig. 1). The Facility concentrates all reconditioning operations on a convenient bench having a length and width of 12 ft by 2 ft, respectively, with the fixtures arranged in a progressive operational sequence. Also, new fixtures and instruments have been designed for the purpose of obtaining safety, economy, and accuracy.

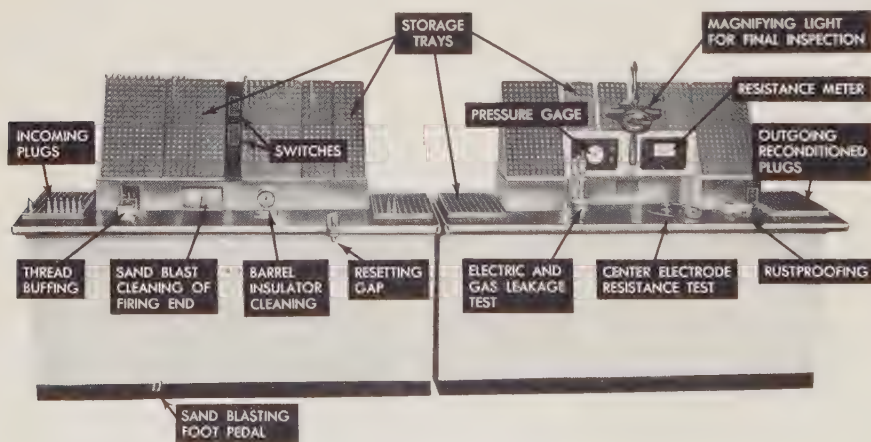


Fig. 1—The Servicing Facility designed and built by AC Spark Plug Division's engineers for reconditioning commercial aircraft spark plugs has greatly increased the output of reconditioned plugs by conveniently locating all necessary equipment required into a compact bench.

Sequence of Reconditioning Operations

Fig. 2 shows a cutaway view of a typical commercial aircraft shielded spark plug and its construction details.

The seat gaskets are first removed from the plugs which are then degreased, dried, and carried to the Facility in a specially designed "buggy" which prevents damage to critical portions of the plug. The plugs then are inspected and those found suitable for reconditioning are placed on the Facility's extreme left-hand shelf.

Eight operations are performed on each plug in the following order as it passes through the Facility: (a) buffing of shield and shell threads, (b) cleaning of spark plug firing end, (c) cleaning of shielding barrel insulator, (d) resetting gap clearance between electrodes, (e) electric breakdown and gas leakage test, (f) center electrode wire resistance check, (g) final inspection, and (h) rustproofing of threads and identification painting.

Buffing of Shield and Shell Threads

The shield and shell threads are cleaned and buffed simultaneously by placing the plug in a sliding fixture and pushing it against a revolving wire brush. This reconditioning operation prevents faulty installation by removing hard deposits of lead and carbon from the threads.

Cleaning of Spark Plug Firing End

The center and ground electrodes as well as the insulator tip are cleaned by an abrasive blasting compound. The plug is first placed into an adapter which is designed specially to fit each type of plug to be cleaned. A foot pedal is then depressed which activates the blasting compound. When the foot pedal is depressed $\frac{1}{3}$ of its travel, a blast of air is applied to the firing end for the purpose of cleaning away blasting compound remnants. The complete cleaning of the firing end enables the energy of the ignition system to be discharged through the gap without any losses caused by leakage along the dirty insulator surfaces.

By ALFRED CANDELISE

AC Spark Plug Division

Individual operations and
equipment concentrated into
compact facility

Cleaning of Shielding Barrel Insulator

The shielding barrel insulator must be cleaned of any accumulated dirt which, if not removed, serves as a conductor of electricity and creates a possible leakage path. The cleaning of the shielding barrel insulator is accomplished rapidly with a specially designed rotating fixture incorporating a rotating rubber plunger and a special cleaning compound. The rubber plunger is inserted into the plug with a slight hand pressure. The plug is cleaned, rinsed with a spray of water, and finally dried with a blast of air. The water spray and air blast are actuated by suitable controls within easy reach of the operator.

Resetting Gap Clearance Between Electrodes

Electrode wear causes a widening of the gap between the electrodes. As the gap increases, the resistance the spark must overcome to jump it also increases. This may result in erratic engine operation and requires a resetting of the gap to the specified value.

Resetting of the gap is performed with the aid of a specially designed gapping fixture having a handle and a pressing tool which make it easy to move the prongs of the ground electrodes until the correct clearance is obtained.

Electric Breakdown and Gas Leakage Test

An electric breakdown test is conducted to ascertain whether the ceramic core is cracked or broken internally. A gas leakage test is conducted to insure that high-pressure gases developed within the combustion chamber will not leak past the plug's seals.

The electric breakdown and gas leakage tests are accomplished through the use of a fixture referred to as a "test bomb." The bomb is an air-tight container having a glass window and a hole for the insertion of the plug. After the plug is inserted into the bomb a locking nut is turned which causes a microswitch to activate automatically an air valve and a high tension circuit. Dry air or other suitable gas is admitted into the bomb until a suitable pressure is attained. High-tension current is then applied to the plug's terminal and sparking is observed through a mirror against which the spark is reflected. The air pressure reading at the spark's point of suppression, shown by a dial located on the Facility's instrument panel, indicates the electrical characteristics of the plug.

Center Electrode Wire Resistance Check

In order to minimize electrode erosion as much as possible the majority of aircraft spark plugs have a resistance of 1,000 ohms nominal value built into the center electrode of the plug as part of the insulator assembly. To check this resistance a specially designed 1-kilovolt resistance meter is used which is not affected by small contact resistances along the path of measurement. The spark plug is first inserted vertically into a fixture with the center electrode in the upward position. A switch is then turned on to energize electrically a needle-like probe which is pressed against the center electrode. The value of the electrode's resistance is indicated on the dial of the resistance meter mounted in a convenient position on the panel facing the operator.

The resistance meter has three scales: (a) 0 ohms to 300 ohms, (b) 300 ohms to 3,000 ohms, and (c) 3,000 ohms to 30,000 ohms. A scale of the correct range can be selected by turning a multiplier dial to an X1, X10, or X100 position. Center electrode resistance checks for aircraft spark plugs can usually be made with the X10 dial. If a warning lamp is lit, however, during a resistance check the next higher scale is used.

Final Inspection

Final inspection of the spark plugs is accomplished with the aid of a lighted magnifier conveniently mounted on the Servicing Facility. The magnifier is used to inspect each plug for (a) cracked or chipped insulator barrels, (b) cracked,

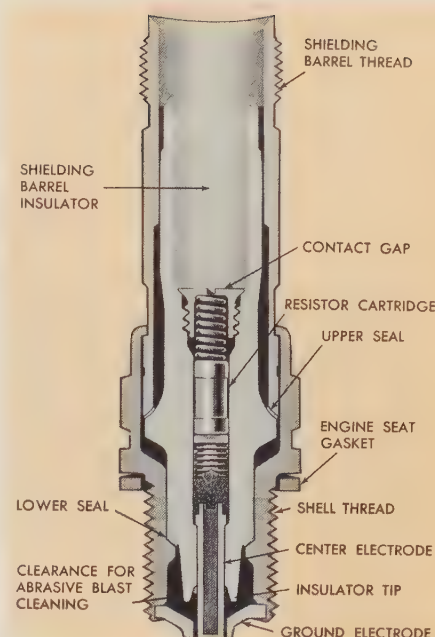


Fig. 2—Commercial aircraft shielded spark plugs are removed from an engine after established periods of operation and are reconditioned for further use with the component parts indicated receiving special attention.

broken, or chipped insulator nose, (c) worn out electrodes, (d) damaged threads, and (e) damaged shell hexagon. When final inspection is completed, the operator places the plug in a tray located to the right of the Facility's inspection area where it is then ready to have the final reconditioning operation performed.

Rustproofing of Threads and Inspection Painting

Rustproofing of threads is accomplished with a motor-operated fixture having a double set of rollers located inside a trough-like box which is filled with the desired rustproofing compound. While the plug is being rotated in this fixture, a paint band is applied to the body of the plug for identification purposes. After the paint has dried, the plugs are packed and stored until ready for use.

Summary

The capacity of the Servicing Facility is approximately five-hundred spark plugs per day per operator. It is well suited for commercial airline requirements and greatly reduces the amount of floor space usually required for reconditioning. Also, economic advantages are realized by conveniently locating the reconditioning equipment in such a manner that all unnecessary handling is kept to a minimum.

GM Colorline Process Simplifies Making of Color Slides

By DANIEL C. WILKERSON
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Engineering Staff

The communication of complex ideas may be accomplished more easily by combined visual and verbal presentation. Aside from functioning to supplement spoken words, visual aids are a necessity in some types of work; engineering, by virtue of its exactness and complexity, generally requires pictorial or graphical illustration. While constantly engaging in communication of technical changes and advances, engineers at the same time are seeking to improve the media of exchange. As a result of work in this field by the General Motors Photographic Section the GM Colorline process for making color slides was developed, affording the advantages of compactness, durability, reduced cost, and ease of preparation.

WITH the present rapid rate of technological progress, the engineer must spend a great deal of his time and attention keeping informed of new developments. In the classroom, in industry, in conferences and training courses, and in technical society meetings, the need has been realized for an efficient, inexpensive means of illustrating complicated scientific subject matter for large audiences. Although many techniques are applicable, projected color slides have become an increasing favorite. To be effective, slides must present an idea in such a manner that the spectator can grasp their meaning clearly and quickly and then devote his entire attention to the technical significance of the information. Slides which confuse the audience tend to detract from the speaker's message.

Careful use of color has been found an invaluable means of making slides more effective. By providing contrast in another dimension, so to speak, color relieves monotony to the eyes. Since engineering slides in one or two colors made from regular art work by color-film processing require considerable time, and the overall cost of color processing is more than black and white, the use of color has been limited.

Faced with the problem of illustrating specific steps in automobile transmission development, the General Motors Engineering Staff began experimenting with color slide techniques in cooperation with the General Motors Photographic Section. (GM Photographic is a separate operating unit of General Motors but is a part of the GM Engineering Staff's facilities.) Portability of equipment and reasonably low cost were primary factors.

After considering and experimenting with photo-color tinting, toning, staining, and other well known techniques, it was decided to try a new diazo single-color film to determine whether or not satisfactory 35 mm slides could be made with this material. GM Photographic has been using diazo materials in a variety of forms for a number of years, but the transparent color sheet has become available only recently. The diazo process is based on the property which certain diazo compounds possess of being altered by exposure to light so that they will not react with a coupler to form stable dye colors, while the unexposed areas will react.

The final method devised for producing color slides from diazo dry-develop transparencies was named the GM Colorline process. Many advantages have resulted from this new technique. To enumerate, Colorline is:

- Compact; slides 2 in. by 2 in. are made from 35 mm film so they can be used in any convenient projector of this size, with or without a screen
- Inexpensive; cost of developing diazo film is considerably less than other color films
- Durable; a special lamination process has been developed for increasing service life
- Quickly prepared; from 20 to 30 slides may be exposed, developed, and mounted in about two hours from available 35 mm copies. More time is required if the 35 mm copies are not ready for use. Copies may be taken directly from the original, cutting additional art work to a minimum.

Visual-verbal presentation
gives improved comprehension,
greater retention

Colorline Process

To make use of the Colorline process a black and white original of the image to be reproduced is required. Although a good photograph would give better results, experience has shown that a reasonably black photostat serves well enough as an original to make a satisfactory slide. Imperfections on negative photostats may be blacked out with India ink or a soft pencil. This is the only necessary art work. Illustrations may be taken from text or reference books, from laboratory charts and graphs, or any other reproducible source.

A black and white 35 mm film copy is made from the original photograph or photostat. The copy may be positive or negative, preferably transparent.

Diazo Film Reproduction

In the current dry-develop diazo reproduction process, a chemical coating is used which is made sensitive to ultraviolet and adjacent spectral light from a projection source. The light-sensitive compounds include both the diazo material and the chemical coupler as well as a stabilizing material. A single sheet of diazo film will produce an illustration of one color and black or white. To obtain two-color or three-color slides, several films with different color characteristics must be mounted together as one slide. A few attractive combinations are white line on a blue background and black line on a yellow or an orange background.

There are about sixty-five forms of paper, translucent stock, and transparent film on which the dry-develop diazo material is coated. Approximately a dozen standard, high-demand varieties are available from the companies now supplying most of the stock.

The 35 mm copy to be reproduced is mounted in a frame in contact with a sheet of the diazo film and exposed to an ultraviolet light source, the exposure time depending on the density of the 35 mm copy. The light at the violet end of the spectrum destroys the color-forming action in the areas most greatly exposed. The dense areas on the 35 mm copy let through less light than the sparse areas, forming colored sections when developed. In other words, the light attack action is patterned by the image on the 35 mm copy, as in photographic printing. Unlike photographic printing, however, the diazo process produces a positive from a positive and a negative from a negative. The image so formed has shading gradations comparable to that of average photographic prints.

Developing

Dry-developing is accomplished by the action of ammonia gas. The film is placed in a bell jar containing an ammonia soaked sponge for 3 min to 5 min, or, if one is available, an automatic machine for making tracing reproductions by the ammonia process may be used. The processing time is comparable to normal blueprint or ammonia-develop printing times, a great improvement over the time required in other color slide techniques.

Mounting

The original slides made by the GM Colorline process were mounted by sandwiching the pieces of diazo film between 2 in. by 2 in. glass plates and binding the edges with adhesive tape. Presently, however, the laminated slides on test are composites of one glass or plastic sheet and a stiff aluminum frame. The laminated mounting technique provides better life and utility for the slide, but for most work ordinary cardboard slide mounts are satisfactory.

Summary

Today, the expanding use of color surroundings in every phase of life makes it increasingly important to avoid the monotony of black and white slide presentations as much as possible. The savings in preparation time, reasonably low cost, versatility, and maximum portability achieved with Colorline slides are expected to increase their use for engineering illustrations. Over 300 Colorline slides have been made in a range of eight different color combinations for showing

Notes About Inventions and Inventors

By STANLEY C. THORPE
Patent Section
Central Office Staff

PREVIOUS issues of the GENERAL MOTORS ENGINEERING JOURNAL have stressed the importance of patenting inventions which currently are in use to prevent their piracy by competitors. It has been pointed out also that the general public benefits from the patent system in that each such competitor is spurred to conceive a different and possibly a better product that does not infringe the patents confronting them. This accelerating, chain-letter-like effect on the production of ideas is an important working partner with free enterprise in guaranteeing a constantly increasing standard of living for everyone.

Many of the inventions which are made, however, prove to be "way ahead of their time" as it is often said. That is, they are not used for one reason or another until sometime after the patents which were granted on them have expired. Such patents teach solutions to the problems which once confronted the inventors and thereby add to the general fund of knowledge, yet when there is no commercial use of these inventions during the life of the patents one might ask, "To what advantage is such a patent to the owner?"

Back in the 1920's General Motors Research Laboratories spent considerable time studying ways of silencing the operation of engine poppet valves. A substantial amount of money for those days was appropriated and spent in designing, building, and testing experimental de-

information pertaining to automobile transmissions—each slide portraying sufficient engineering detail to be useful in specific design work and instruction. This new slide facility also allows fast preparation of color slides for short-notice program presentations.

A variety of new applications are foreseen for the process. With the field of color photo-reproduction expanding rapidly for the average camera user,

Early patenting of "non-commercial" inventions in active fields may prove wise investments

signs. Numerous mechanical as well as hydraulic arrangements were tried, modified, and rejected before anything evolved having much promise of accomplishing the result sought. Several variations of the hydraulic type began to attract the most interest. In one of these, the so-called "full hydraulic" system, the valve tappet acted as a plunger in one end of an oil-filled chamber fixed to the engine. A piston in the other end of the chamber drove the valve. In a second hydraulic design, a movable dash pot in the valve operating train took the place of the fixed chamber. A third form of the hydraulic type had the dash pot fixed to the engine and a plunger therein served as a yielding reaction member for a rocker in the camshaft-to-valve operating train.

At the time, it was believed that the "full hydraulic" arrangement had the best commercial possibilities and a number of patents were applied for in order to protect the investment in time, labor, and materials expended on its development. No commercial use, however, ever materialized.

some adaptation of the Colorline process conceivably could be developed for amateur home processing. The flexibility of projection equipment for 35 mm slides also extends their range of use, since they can be projected in any 2 in. by 2 in. projector. While the slides made thus far in developing the GM Colorline process have been limited to 35 mm film, larger composite transparencies can be made using this technique.

The third form, rather than the second, received the next largest share of the engineering and research efforts, and eventually was adopted and used for a number of years in the Cadillac V-16 and V-12 automobiles and in certain bus engines. This design was, of course, also patented and licenses were granted to other manufacturers. Due principally to its higher production costs, however, this design was never adopted on the lower priced, high production volume cars, and it was eventually discontinued in favor of a competitors' product more similar to the Research Laboratories' second design.

Notwithstanding the earlier belief that this second design had relatively little prospect of commercial use, various embodiments of it were patented. The claims in these patents, however, were necessarily of more limited scope than could be obtained on the other two because of the existence of a prior patent on the broad idea—a patent which was purchased by General Motors shortly prior to its expiration.

Later, the time came when General Motors desired to manufacture its own "hydraulic valve lifters"—the term now commonly used in identifying devices like the second design. Meanwhile, other manufacturers had entered the field and taken out patents of their own—some of which covered the specific design features of the lifters which Cadillac Motor Car had been using since discontinuing the Research Laboratories' design originally adopted in the V-16 and V-12 cars.

However, because of the earlier GM patents, particularly those on the Research Laboratories' second design, General Motors still was able to use the basic features of that design even though there were later patentees in the field. Thus General Motors lifters of essentially this design were put into production, and with some subsequently patented improvements have since become one of the principal products of the GM Diesel Equipment Division.

Of course, it does not follow from this episode that every invention of doubtful commercial application warrants patenting. However, where the invention has significant novelty and is in a field under active development, such patents may yield a return far exceeding their cost by keeping later patents of others from blocking the way when the commercial situation changes.

On this and on the following pages are listed some of the patents granted to General Motors prior to August 31, 1955. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

Patents Granted

- **Robert W. Burton**, *Cadillac Motor Car Division, Detroit, Michigan, for a Vibration Dampener for a Vehicle Drive Shaft Housing, No. 2,707,032, issued April 26.* This patent covers the use of a resiliently mounted weight for dampening vibration of the extended end of a rigid transmission drive shaft housing.

Mr. Burton is a senior project engineer in Cadillac Motor Car's Engineering Department. In 1936 Mr. Burton joined the Division as a General Motors Institute student. In 1940, after being graduated from G.M.I., he was made a technician in the Engineering Laboratory, was promoted to research engineer in 1945, and to his present position in 1950. Mr. Burton is the author of the paper "Special Problem Road Testing," published in the February 1951 *S.A.E. Journal*. He also served as a plant representative of the S.A.E. and on its Membership Committee.

- **Harry D. Martin**, *New Departure Division, Bristol, Connecticut, for a Separator for Antifriction Bearings, No. 2,712,481, issued July 5.* This patent relates to a separator for circumferentially spacing the rolling elements between a pair of race rings in an antifriction bearing. This separator is provided with resilient linings in its rolling element-receiving pockets to cushion the rolling elements as well as to provide quiet bearing operation.

Mr. Martin is chief physical test engineer in the Product Engineering Department at New Departure. He graduated from Pratt Institute as an industrial-mechanical engineer in 1928 and shortly thereafter joined New Departure as a junior test engineer. He was made supervisor of the Physical Test Laboratory in 1932 and held this title until 1943 when he was promoted to chief inspector

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.



of the Ordnance Plant which was devoted to the production of large bearings for military use. In 1945 he was attached to the staffs of the chief engineer and the manager of Research and Development. Seven years later he was promoted to his present title. Mr. Martin is a member of the Society of Automotive Engineers.

- **Clifford H. Wurtz and Leland H. Grenell**, *Frigidaire Division, Dayton, Ohio, for a Refrigeration Evaporator, No. 2,712,736, issued July 12.* This invention relates to a roll forged refrigerant evaporator in which an accumulator chamber is formed as an integral part of the evaporator and in which the walls of the accumulator are forge welded together at a plurality of spaced points so as to prevent bulging of the side walls when subjected to high internal pressures.

Mr. Wurtz is supervisor of the major product line at Frigidaire. Directly after earning the B.S. degree from University of Illinois in 1929, he joined this Division. After completing an engineer-in-training program he was made a junior tester and, in early 1938, was promoted to senior tester. Later in the same year, he advanced to junior engineer and in 1942 was promoted to senior engineer. In 1950 he was appointed section engineer and, two years later, was promoted to his present position. His previous projects have included work on the development of the Cyclo-Matic system of automatic defrosting.

Mr. Grenell is supervisor of the Metals Section in Frigidaire's Engineering Division. In Mr. Grenell's 15 years with the Division he has concentrated on work with metals, leading to two granted patents and several published papers. He earned the B.S. degree from Pennsylvania State College in 1924. Mr. Grenell is a member of the American Institute of Mining and Metallurgical Engineers, the American Society for Metals, and serves on the American

Society for Testing Materials' Committee B5 on Copper Alloys. Prior to joining General Motors, he was employed by the U. S. Bureau of Mines, the Bureau of Standards, and Battelle Memorial Institute.

- **William D. Howell**, *AC Spark Plug Division, Flint, Michigan, for a Water Gage Tank Unit, No. 2,713,264, issued July 19.* This invention relates to electrical liquid level gages wherein a flexible tube encases a rotating rod with one end sealed to the rod and the other end sealed to the stationary bearing for the rod, thus waterproof sealing a variable resistance from the liquid

Mr. Howell serves AC Spark Plug as a senior project engineer in its Experimental Engineering Department. In his present capacity, Mr. Howell is supervisor of automotive instrument design. He joined the Division in 1928, two years after earning the B.S. degree in electrical engineering from Michigan State University of Agriculture and Applied Science. He was made designer in 1933, layout man in 1934, senior layout man in 1944, and promoted to his present position in 1948. He is a member of Tau Beta Pi and Phi Lambda Tau, honorary engineering societies.

- **Lauren L. Johnson**, *Electro-Motive Division, LaGrange, Illinois, for a Battery Charging Control, No. 2,713,659, issued July 19.* This patent is on a voltage cut-out relay under permanent opposed biases from charging generator and battery to connect and disconnect generator and battery.

Mr. Johnson is an electrical control development engineer in the Engineering Department of Electro-Motive. He received the B.S.E.E. degree from University of Nebraska in 1938. Mr. Johnson began his career with General Motors in 1944 as a project engineer and assumed his present position in 1952. Currently, he is engaged in work on new model locomotives and oil well drilling rigs. Mr. Johnson is a member of the American Institute of Electrical Engineers' Committee on Land Transportation. Six patents in the fields of locomotive control and electronic frequency changes for power and induction heating have resulted from his work.

- **Harry R. Stocks**, *Vauxhall Motors, Limited, Luton, England, for Windscreen*

Wipers, No. 2,713,178, issued July 19. This invention relates to a mechanical drive transmission connecting a motor to a windshield wiper blade and having a crank connection and a crossed link connection to drive the windshield wiper with substantially simple harmonic motion to reduce the speed and shock at the end of the wiper path.

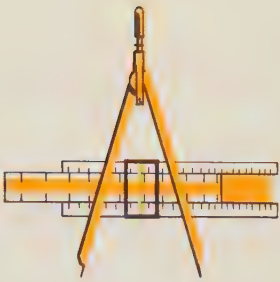
Mr. Stocks is assistant chief engineer at Vauxhall Motors. Starting in 1933 as a draftsman in Vauxhall Motors' Engineering Department, his list of promotions includes truck design engineer (1937), armored fighting vehicle design engineer (1940), passenger vehicle engineer (1950), and his present position, assistant chief engineer (1953). Mr. Stocks' work with brake design, windshield wiper mechanisms, electric switches, and sliding window mechanisms has led to a total of five granted patents.

- **Gordon W. Harry and William E. Barnes**, *AC Spark Plug Division, Flint, Michigan, for a Fuel and Vacuum Pump with Hand Primer, No. 2,713,830, issued July 26.* This patent relates to a pump adapted for use especially with gasoline engines and involves a hand primer which is readily accessible and suitable for rugged or military service.

Mr. Harry serves as staff engineer at AC Spark Plug. He was originally employed by the Division as a designer in 1925. Since then he has advanced through the positions of junior engineer, assistant experimental engineer, assistant section engineer, development engineer, and experimental engineer to his present position. His current major projects deal with fuel pumps and vacuum pumps. Mr. Harry received the B.S. degree in mechanical engineering from University of Michigan in 1923. He is a member of the Society of Automotive Engineers and is a registered professional engineer in the state of Michigan.

Mr. Barnes is an experimental engineer in AC Spark Plug's Experimental Engineering Department. He has been with this Division for nearly seventeen years, starting as a layout engineer in the Engineering Department. At present,

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.



Mr. Barnes is concerned primarily with work on solid fuel injection systems and injection pumps. He received the B.S. degree in mechanical engineering from Tri-State College, Angola, Indiana, in 1931. He is a member of the Society of Automotive Engineers. Mr. Barnes served in the Navy from July 1942 until November 1945, separating with the rank of lieutenant commander.

- **Walter B. Herndon**, *Detroit Transmission Division, Ypsilanti, Michigan, for a Selective Automatic Drive, No. 2,713,798, issued July 26.* This patent is for a particular simplified three-speed automatic transmission which could be used instead of the present Hydra-Matic. It is of the countershaft type in which the gears are constantly in mesh. The appropriate gear is placed in the power train or removed from it by one of a pair of clutches energized hydraulically under the joint control of car speed and engine throttle. The transmission is urged to shift up as car speed increases and upshifting is opposed in accordance with torque demand (as indicated by throttle opening), as is usual in automatic transmissions.

Mr. Herndon serves as works manager at Detroit Transmission. He began his engineering career with GM in 1928 as a tool designer at the Cadillac Motor Car Division. In 1939 he transferred to the Central Office Engineering Staff as a project engineer. When Detroit Transmission was formed in the same year, he transferred to the new Division's Engineering Department and later was made assistant to the general manager. His subsequent promotions include assistant chief engineer, chief engineer, director of Engineering and Sales, and works manager. Mr. Herndon figured prominently in the initial design work and production of the Hydra-Matic automatic transmission. As a result of his extensive work in the field of automatic transmissions, Mr. Herndon has been responsible for 10 patent applications.

Mr. Herndon was graduated in 1928 from State College of Washington with the B.S.E. degree. He received the M.S.E. degree in 1930 from University of Michigan.

- **Joseph D. Turley**, *Buick Motor Division, Flint, Michigan, for a Self-adjusting Tappet, No. 2,713,856, issued July 26.* This patent relates to a mechanical self-adjusting tappet providing a predetermined valve lash which is maintained by means of an externally and internally threaded spring biased sleeve between the tappet body and the push rod.

Mr. Turley is a staff engineer in Buick Motor's Special Projects Department, concentrating on engine and transmission projects. He was employed in 1929 as a detailer in Buick Motor's Engineering Department. Frequent promotions led to his present position in 1950. Mr. Turley received the B.S. degree in mechanical engineering in 1928 from Oregon State College. He is co-author of a paper on the Buick V-8 engine, published in the January 1953 *Society of Automotive Engineers Journal*.

- **Arthur J. Frei**, *Inland Manufacturing Division, Dayton, Ohio, for an Ice Tray Grid, No. 2,714,294, issued August 2.* This patent discloses a triple row ice block forming grid and freezing tray in which initial force applied to the hand lever is utilized for breaking the grid and ice blocks adhering thereto loose from the tray before any force is transmitted to other grid walls to harvest additional ice blocks from the grid.

Mr. Frei serves Inland Manufacturing as a senior project engineer in its Engineering Department. He has been with Inland Manufacturing since 1934 when he began as a draftsman in this same Department. Two years later he was advanced to designer and in 1944 he was made project engineer. One year later he was promoted to senior project engineer—his present position. Previously, Mr. Frei was concerned with developmental work on steering wheels and running boards. His current major project, design and development of ice trays, has resulted in four granted patents.

- **L. C. Wolcott**, *Packard Electric Division, Warren, Ohio, for a Nonmetallic Conductor, No. 2,714,623, issued August 2.* This patent relates to a conductor having a core of threads, linen, silk, or the like, covered by a braided cover of similar thread



impregnated with graphite or other suitable nonmetallic conducting material. The core is covered with a layer of latex which acts as bonding material between the impregnated core and an outer insulating sheath which surrounds the latex.

Mr. Wolcott has served as chief engineer of Packard Electric since 1933. He has been with the Division's Product Engineering Department since his employment in 1927 as an aviation sales engineer. Mr. Wolcott holds an electrical engineering degree from Lehigh University (1925) and the M.B.A. degree from the Harvard Graduate School of Business (1927). His work with automotive wiring and cables has led to five granted patents and a published paper on the design and installation of wiring systems for commercial vehicles (*S.A.E. Transactions*, April 1949). He is a member of the S.A.E. Aircraft Electrical Equipment Committee and the Safe Electrical Cord Committee of the National Electrical Manufacturers Association.

- **Robert H. Bauman**, *Moraine Products Division, Dayton, Ohio, for an Automatic Brake Wear Adjuster, No. 2,714,941, issued August 9.* This patent relates to a mechanism for effecting brake adjustment automatically as the brakes wear.

Mr. Bauman is a senior layout man in the Engineering Department of Moraine Products. In May 1933 he joined the Machine Department of Frigidaire Division, transferred one month later to Inland Manufacturing Division, and joined Moraine Products in 1946. This is the first patent granted as a result of Mr. Bauman's work with brake design. He is a former member of the American Society of Tool Engineers and the Foreman's Association of America.

- **Mearick Funkhouser**, *Delco Products Division, Dayton, Ohio, for a Shock Absorber with Floating Baffle, No. 2,714,942, issued August 9.* This patent relates to a shock absorber having a partition in the reser-

voir to reduce oil frothing.

Mr. Funkhouser is chief engineer of Delco Products. In 1933 Mr. Funkhouser started at this Division as an inspector. He was promoted through the positions of laboratory engineer in the Shock Absorber Laboratory in 1933, senior design engineer in 1942, section engineer in 1944, and assistant chief engineer in 1945, to chief engineer—his present position—in 1951. Mr. Funkhouser earned the mechanical engineering degree in 1932 from Cornell University. He is a member of the Society of Automotive Engineers.

- **Robert W. Leland and Krell E. Spires, Jr.**, *Delco Products Division, Dayton, Ohio, for an Electric Circuit Control, No. 2,714,807, issued August 9.* This patent relates to an electrical control device for selectively connecting two devices to a source of power but with a time lag between disconnection of one device and connections of the other.

Mr. Leland, a staff engineer at Delco Products, is in charge of product design on hermetic motors, fan motors, capacitors, and control devices. His work in the field of electrical control devices has led to six granted patents. Mr. Leland joined the Division in 1933 as a University of Cincinnati co-op student (receiving a degree in electrical engineering in 1937), was promoted to section engineer in 1947, and was advanced to his present position in January 1955. Mr. Leland is a member of the Engineers' Club of Dayton, the National Association of Foremen, and the American Institute of Electrical Engineers.

Mr. Spires is a project engineer at Delco Products. He received the B.S. degree in mechanical engineering from Case Institute of Technology in 1945 and joined Delco Products as a student engineer in October of the following year. At present, he is concerned with the development of electrical devices embodying thermal ("hot wire") actuation. His work had led to two granted patents in this field. Mr. Spires is a member of the Engineers' Club of Dayton.

- **James W. Light and Howard M. Geyer**, *Aeroproducts Operation of Allison Division, Dayton, Ohio, for a Synchronizing Apparatus, No. 2,715,206, issued August 9.* This patent relates to means for synchronizing the speeds of two rotating devices, such as variable pitch propellers, by varying the speed of one device in response to a speed

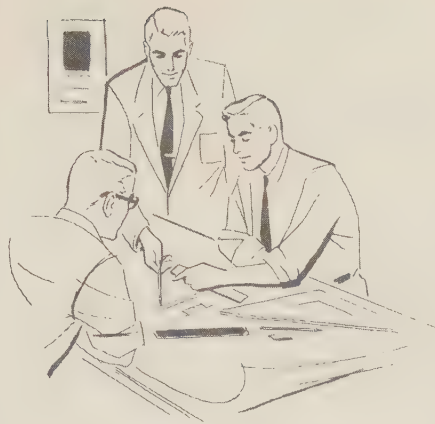
difference between the devices as sensed by electrical speed comparing apparatus.

Mr. Light is an experimental engineer in the Engineering Department of Aero-products. He joined this organization in 1941 as a test operator. In 1943 he was promoted to a special tester and assumed his present position in 1945. He is engaged, at present, in developmental work on AAHL-A1 actuators (controls) and previously has done work on locking hydraulic actuators. Mr. Light attended Miami University and The Ohio State University. His work has resulted in several granted patents, including one on a propeller-speed controller and another on a biasing-type electronic synchronizer.

Mr. Geyer serves as chief product research engineer at Aero-products. He earned the B.S. degree in industrial engineering from University of Alabama in 1940. He joined Aero-products in August of the same year as a junior draftsman and advanced through the positions of designer, senior designer, and senior project engineer until promoted to his present position. At present, he is concerned with dual-drive servo control mechanisms.

• **Webster J. Owen, John F. Gordon, and Philip W. Maurer**, *Cadillac Motor Car Division, Central Office, and Cadillac Motor Car, respectively, Detroit, Michigan, for a Refrigerating Apparatus, No. 2,782,808, issued August 9.* This invention relates to an automobile air conditioning system which provides for improved air distribution in the car and for improved control of the refrigeration system so as to maintain greater comfort in the conditioned space.

Mr. Owen is an assistant staff engineer assigned to heating and air conditioning projects in the Engineering Department of Cadillac Motor Car. While a student at Beloit College, Wisconsin, Mr. Owen joined the Janesville Chevrolet plant as an assembler. In 1936, after earning the B.S. degree in chemistry, he transferred to Cadillac Motor Car as a co-operative student. His most recent promotion, assistant staff engineer, occurred in 1950. He is a member of the Society of Automotive Engineers.



Mr. Gordon is vice president of General Motors and group executive in charge of body and assembly plants. He was appointed to this post on January 1, 1951 and at the same time was elected to the Board of Directors and to the Administration and Operations Policy Committees. Mr. Gordon was general manager of Cadillac Motor Car from 1946 to 1950 and he served as vice president of GM's Engineering Staff shortly before his present appointment. He was graduated from the U. S. Naval Academy in 1922 and a year later obtained the M.S. degree in engineering from University of Michigan. He then joined Cadillac Motor Car where he rose through the Engineering Department becoming motor engineer and finally chief engineer in 1943. Mr. Gordon is chairman of the Board of Regents of General Motors Institute and he is a member of the S.A.E., the Engineering Society of Detroit, and the American Ordnance Association.

Mr. Maurer, as staff engineer—electrical and accessories at Cadillac Motor Car, is responsible for the design and release of all electrical and accessory items, including air conditioning, on Cadillac automobiles. In 1930 Mr. Maurer joined the Division as a General Motors Institute co-operative student. In 1934, after earning a certificate in automotive engineering from G.M.I., he was transferred to the Technical Data Department, was promoted to assistant accessory engineer in 1936, to assistant electrical engineer in 1940, and to his present position in 1950. Mr. Maurer is a member of the Engineering Society of Detroit and serves on the S.A.E. Subcommittee on Radio and Television Interference.

• **Duward C. Staley**, *General Motors Patent Section, Dayton, Ohio, for a Motor Stator and Method of Manufacture, No. 2,715,193, issued August 9.* This patent relates to a method for welding laminated motor stators.

Mr. Staley is a patent attorney in the Dayton Office of the Patent Section. He started with GM in 1926 as patent draftsman in the Patent Section of Delco Products Division. The next year he transferred to Frigidaire Division's Patent Section. From 1940 to 1952 when he returned to GM in his present post, Mr. Staley was connected with a patent law firm in Dayton. Mr. Staley was granted the LL.B. degree from University of Dayton in 1936. He is a member of the bar of the State of Ohio and of several law and patent societies.

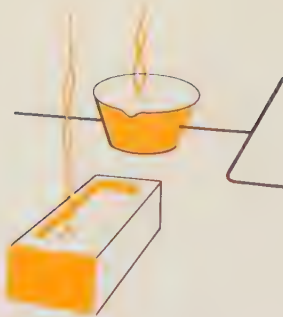
• **Carl J. Wampole**, *Delco-Remy Division, Anderson, Indiana, for an Assembling Mechanism, No. 2,714,761, issued August 9.* This patent is directed to an automatic machine for assembling the various parts of a switch wherein the operating member is a push-pull rod. All of the parts of the switch are supplied to separate hoppers in the machine wherein workholders progressively carry the parts from one station to the next as additional parts are assembled in the workholder until a finished product is obtained.

Mr. Wampole currently serves as a tool designer at Delco-Remy, having been engaged in the building and design of tools and fixtures for over thirty years. He joined this Division in 1925 as a tool maker and became tool designer in 1945. His present work is related primarily to the design of special fixtures.

• **David A. Galonska**, *Saginaw Steering Gear Division, Saginaw, Michigan, for a Scissors Jack, No. 2,716,537, issued August 30.* This invention relates to an automotive jack of the scissors type having a collapsible handle which may be used to slide the jack under the vehicle and to locate the jack so that it will engage a frame member to lift the vehicle.

Mr. Galonska serves as a senior project engineer at Saginaw Steering Gear. In this capacity, he is concerned with all applications of ball-bearing and screw and nut assemblies. Mr. Galonska started with Saginaw Steering Gear in 1940 as a tool designer and transferred to the Product Engineering Department in 1943 as a designer. He also served for three years as experimental engineer-in-charge

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.



of the Physical Test Laboratory and Model Shop before appointment as project engineer in 1952. Mr. Galonska was appointed senior project engineer-in-charge of actuator engineering in 1954.

• **Homer R. Hastings**, *AC Spark Plug Division, Flint, Michigan, for a Variable Resistor for Liquid Level Telemetric System, No. 2,716,685, issued August 30.* This patent pertains to a unit in a liquid level telemetric system and adapted to be installed in a vehicle gasoline tank, the unit including a rotative electrical resistance unit with stationary contacts having leads easily connected to a gasoline gage on the vehicle instrument panel.

Mr. Hastings serves AC Spark Plug as a senior project engineer in its Product Engineering Department. Presently, he is concerned with the design and development of automotive gages. Mr. Hastings received the B.S. degree in electrical engineering from Michigan State University of Agriculture and Applied Science in 1939. That same year he joined AC Spark Plug in the Works Engineering Department. Mr. Hastings is a registered professional engineer, State of Michigan, and, in addition, is a member of the S.A.E., is chapter and state director of the Michigan Society of Professional Engineers, and is a former director of the American Institute of Electrical Engineers.

• **Harry A. Mackie and Louis P. Garvey**, *General Motors Styling Staff and Fisher Body Division, respectively, Detroit, Michigan, for Windshield Wipers, No. 2,716,252, issued August 30.* This invention relates to a cable transmission for connecting a motor to drive a windshield wiper blade and having simplified automatic cable slack adjusters which maintain a uniform tension on the cables.

Mr. Mackie is a supervisor in the Body Development Studio of the General Motors Styling Staff. He received the B.S.M.E. degree from Louisiana State University in 1936 and began his career

with General Motors in 1941 as assistant division engineer in the Fisher Body Aircraft Section of Central Engineering in Memphis, Tennessee. In 1945 Mr. Mackie became division engineer of the Fisher Body Aircraft Section and was promoted to senior design project engineer in 1947. He is a member of the Society of Automotive Engineers and is a registered professional engineer. Mr. Mackie's work has resulted in four granted patents.

Mr. Garvey is senior project engineer in the Experimental and Development Section of Fisher Body. He was initially employed by Fisher Body in 1946 as a layout draftsman. Subsequently, he became senior layout draftsman and senior designer before appointment to his present position in 1952. Some of Mr. Garvey's previous major design projects related to vertical seat adjusters, windshield wipers, and Le Sabre experimental-automobile convertible top linkage and controls, and he is currently working on automatic seat control systems. He received the B.M.E. degree in 1940 from University of Detroit and is a registered professional engineer.

• **Wesley W. McMullen**, *AC Spark Plug Division, Flint, Michigan, for a Crankcase Ventilation Valve incorporating Flame Arrester, No. 2,716,398, issued August 30.* This invention relates to a valve for controlling the flow of crankcase vapors to the intake manifold of an engine. The valve is also constructed to close in the event of a backfire to prevent crankcase explosions.

Mr. McMullen is a staff engineer in AC Spark Plug's Automotive Engineering Department. In this capacity, he is in charge of the engineering of automotive air cleaners and silencers and of crankcase ventilation, the subject of this patent. He has been with this Department since 1934 when he joined as a student engineer. Mr. McMullen holds the B.S. degree in mechanical engineering from University of Michigan (1934). He is a member of the Society of Automotive Engineers and serves on the Carburetor Air Horn and Flanges Subcommittee of this Society's Engine Committee.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

Technical Presentations by GM Engineers

The General Motors Divisions and Staffs are glad to make information available to the public about recent engineering developments and facilities. One of the ways of accomplishing this is through the medium of the speaking appearance. Engineers and technical personnel have presented papers and served as panel members of technical society meetings and many have spoken in college classrooms and before civic organizations. Grouped below are the most recent of the speaking engagements filled by GM engineers.

Aeronautical Engineering

Floyd G. Dougherty, chief of the Combustion Section, and **M. C. Hardin**, supervisor of fuels and lubricants in the Combustion Section—both of the Aircraft Engines Operations of Allison Division—gave a joint presentation at the September 15 meeting of the National Petroleum Association, held in Atlantic City. The title of their paper was "Fuel Requirements for Commercial Gas Turbine Aircraft."

On September 27, before the Cincinnati Section of the Society of Automotive Engineers, **William B. Seaver**, engine project engineer—commercial T56, Power Turbine Engineering Section of Allison's Aircraft Engines Operations, discussed "The Allison T56 Turbo-Prop Aircraft Engine."

At the Rufus King High School students and parents guidance meeting held on October 19 in Milwaukee, **Arthur Brown**, senior design engineer in the Jet Engine Control Engineering Department in the Milwaukee plant of AC Spark Plug Division, talked on "The Opportunities in Aeronautical Engineering."

Air Conditioning

Webster J. Owen, assistant staff engineer—electric and accessories, Cadillac Motor Car Division, addressed the Amer-

can Society of Refrigerating Engineers at Dayton, Ohio, on September 12. Mr. Owen discussed "Automobile Air Conditioning—1955."

J. Ralph Holmes, chief engineer at Harrison Radiator Division, spoke on "Automotive Air Conditioning" at the October 18 meeting of the Lockport, New York, Rotary Club.

Automotive Engineering

On August 25, **G. A. Delaney**, chief engineer of Pontiac Motor Division, described the "Engineering of a New Car Model" to the GM Tech Club meeting in Anderson, Indiana.

During the Golden Anniversary Meeting of the S.A.E. held in Cleveland on September 12, **Maurice Olley**, special assistant to the chief engineer of Chevrolet Motor Division, presented "A Report on New Suspension on Commercial Vehicles."

"Radiator Pressure Caps" was the title of the paper prepared by **Jesse E. Eshbaugh**, staff engineer in the Automotive Engineering Department of AC Spark Plug's Flint plant, and read by **David Keil** at the September 13 meeting of the Michigan Trucking Association held in Detroit. During the same meeting, **Carleton J. Lauer**, staff engineer in this same Department, talked on "The Filtration of Automotive Crankcase Oils."

E. H. Holtzkemper, staff engineer in the Engine Department of Buick Motor Division, addressed the Canton-Alliance-Massillon Section of the American Society of Mechanical Engineers in Canton, Ohio, on September 21. He discussed "Passenger Car Engine Trends."

On September 22, at a meeting of the American Society of Body Engineers held in Detroit, **James E. Goodman**, vice president of General Motors and general manager of Fisher Body Division, made the presentation "Looking Forward with the Body Engineer."

On September 23, **Walter R. Mackenzie**, director of Product Information and Public Relations of the Engineering Department, Chevrolet Motor, participated in a radio interview on the subject "Why Chevrolets Are Winning Stock Car Racing Events" during the program "World of Speed" conducted over station WXYZ, Detroit.

Mauri Rose, special engine and vehicle development engineer at Chevrolet Motor, addressed the Fort Wayne Engi-

neers' Club in Indiana on October 20. The title of Mr. Rose's talk was "Horsepower and People."

Electronics

On September 15 **M. G. Wright**, head of Delco Radio Division's Mechanical Engineering Department, gave a talk before A.S.M.E. members of the Central Indiana Section at a meeting held in Kokomo. The title of his presentation was "Mechanical Design of a Signal Seeking Tuner."

Harold Hogan, senior project engineer in the Test Laboratory at AC Spark Plug, Milwaukee, took part in the National Electronics Conference held in Chicago on October 5. Mr. Hogan talked on "Stability Boundaries for Fifth Order Servomechanisms."

Engineering Management

Lloyd Christenson, assistant director of AC Spark Plug's Production Engineering Department in Flint, took an active part in the Creative Engineering Laboratory sponsored by Massachusetts Institute of Technology during its summer session. He lectured on the "Management of Creative People."

Kenneth A. Meade, director of the Educational Relations Section, Central Office Department of Public Relations, addressed a joint meeting of the North-eastern Michigan Section of the American Institute of Electrical Engineers and the Michigan Society of Professional Engineers held in Flint on September 13. Mr. Meade's talk was entitled "Professional Engineering Ethics in Practice."

At the 10th Annual Industrial Engineering Conference held in Chicago on September 22, **Walter Eitel**, superintendent of the Production Engineering Department of AC Spark Plug, Flint, outlined "Team Organization for Effective Use of Engineers."

Metallurgy

"Vacuum Melted Metals" was the title of the talk given by **Charles E. Norton** before the American Society for Metals meeting in Philadelphia on October 17. Mr. Norton is the chief Metallurgist in New Departure Division's Metallurgical Laboratory of Product Engineering.

"How Can Potentially Creative Design and Development Engineers Be Identified Early in their Careers?" was the talk given by **Donald A. Long** at the A.S.M.E. Engineering Supervisors Seminar held on September 29 in Rochester, New York. Mr. Long is the supervisor of education and training in the Personnel Department of Rochester Products Division.

General Engineering

Dean P. Roberts, farm distributor representative in Delco Products Division's Sales Department, spoke at the Mississippi Federated Farm Co-operative meeting held in McGee, Mississippi, on August 12. Mr. Roberts discussed "Grain and Hay Drying."

T. W. Meeder presented the talk "New Facilities Proposal" at the Naval Air Turbine Test Station on August 19. Mr. Meeder is a plant engineer in the Aircraft Engines Operations of Allison.

Jack Walker, who is a methods engineer in the Work Standards Department of Buick-Oldsmobile-Pontiac Assembly Division's Atlanta plant, outlined the "Organizational Structure of General Motors—Primarily the B.O.P. Plant at Atlanta" to engineering students at the Georgia Institute of Technology on September 1.

At the Civitan Club meeting of September 6 in Dayton, **Claude M. Willis**, safety director of Delco Products' Safety Department, gave a talk on "Highlights—Grand American Handicap and How It is Operated."

During the Michigan Safety Conference held in Lansing on September 14, **A. J. Dunkle** chose as his topic the woman's place in industry, presenting a talk entitled "Women Are Not Little Men." Mr. Dunkle is the director of work standards in the AC Spark Plug Flint plant's Efficiency Department.

Another of AC Spark Plug's technical personnel—**Robert A. Hard**, project engineer in the Defense Engineering Department (Flint)—appeared before a class at the Congregation Unitarian Church on October 2. He talked on "Prehistoric Man in Michigan."

Howard W. Brandt, general manager of Rochester Products, presented a talk entitled "A Young Man in Business" to the Junior Chamber of Commerce of Rochester, meeting on October 10.

On October 7 **Robert E. Tuttle**,

assistant chairman of the English and Psychology Department, General Motors Institute, lectured on "The Importance of Communication to the Technical Man" as part of the Technical Expression Institute held at the University of Wisconsin.

Before the University of Detroit Student Section of the S.A.M.E. meeting on October 12, **John Burnell**, design engineer in the Engine Design Group of Chevrolet Motor, outlined "The Design and Development of an Engineer."

K. A. Stonex, was on the program of the 25th Annual Conference of the Institute of Traffic Engineers held in Pittsburgh on October 25. Mr. Stonex, who is head of the Technical Data Department at the General Motors Proving Ground, described the "Lessons Learned by the Proving Ground Engineer in Highway Design and Traffic Control."

Maurice Olley, special assistant to the chief engineer of Chevrolet Motor, addressed the Akron, Ohio, Council of Engineering and Scientific Societies on November 2. Mr. Olley talked on "Reminiscences of Progress."

Heavy-Duty Equipment and Off-the-Road Vehicles

Two GM Divisional personnel were on the program of the S.A.E. Golden Anniversary Tractor Meeting and Production Forum held in Milwaukee from September 12 through 15. **H. C. Kirtland**, chief applications engineer in the Transmissions Engineering Department of Allison, presented the paper "Torqmatic Drive—Its Part in Easy Mobility." As part of the same panel discussion on twin power for easy mobility, **R. C. Williams**, manager of crawler tractor engineering in Euclid Division's Engineering Department, presented "Twin Power Tractor Development."

A. S. McClimon appeared before the Northern California Chapter of the S.A.E. on November 1, discussing "Today's Earthmoving Equipment." Mr. McClimon is manager of the Sales Development Department at Euclid.

Another member of the Sales Development Department, **Don S. Graham**, chief application engineer, described "The Twin Power Euclid Crawler Tractor" at the November 8 meeting of the Muskegon Chapter of the S.A.E.

Industrial Engineering

Starting with the 1955 fall term, **John Schneiders**, time study man in the Standards Department of Delco Products, is conducting a course in time study at the University of Dayton.

On August 18 and again on September 22, **Leo J. Nartker**, superintendent of Delco Products' Quality Control Department, outlined "The Use of Statistical Methods in Industry" before engineering groups of the United States Air Force Reserves, Dayton, Ohio.

As part of the Industrial Safety Forum conducted by the Dayton Chamber of Commerce on September 20, **Ray C. Hoefling**, supervisor of the Tool Design Department of Delco Products, discussed "Safety as It Pertains to Tool Design."

"Industrial Engineering and Its Relation to Tool Engineering" was the talk given by **Edward A. Reed**, General Motors Institute, before the Chapter 1, Education Section of the American Society of Tool Engineers, meeting in Detroit on September 22. Mr. Reed is assistant chairman of the Institute's Industrial Engineering Department.

Cleveland F. Nixon, head of the General Motors Research Staff's Electro Chemistry Department, presented "A Problem for the Plater" at the September 26 meeting of the American Electroplaters Society, held in Syracuse, New York.

During the period covered in this report, **Howard K. Gandelot**, safety engineer in the GM Engineering Staff's Vehicle Safety Section, completed two speaking engagements: October 6 he described "Safety Progress in Commercial Vehicles" at the 6th Annual Governor's Traffic Safety Conference, Sacramento, California, and on October 12 he outlined the "Advancement in the Performance and Safety of Automobiles" before the Madison County Industrial Club, Anderson, Indiana.

At the October 21 meeting of the American Society for Testing Materials in London, Ontario, Canada, **John Q. Holmes**, supervisor of equipment and operations in the Production Engineering Section of the General Motors Manufacturing Staff, discussed "Production Engineering."

Francis L. Mackin, chairman of the Machine and Woodshops Department, General Motors Institute, served as

chairman of a technical panel discussion on "Hydraulic Fluids" at the National Conference on Industrial Hydraulics. The Conference was held in Chicago on October 27.

Industrial Research

During the 2nd Midwestern Conference on Solid Mechanics held at Purdue University from September 8 to 10, **Leonard G. Johnson** read his paper entitled "Stresses in an Infinite Plate with a Circular Hole Subjected to a Cosine Pressure Distribution of Period 180°." Mr. Johnson is a senior mathematician in the GM Research Staff's Special Problems Department.

As part of the Symposium on Air Pollution conducted during the 128th National American Chemical Society Meeting in Minneapolis, September 11 through 16, **George J. Nebel**, research engineer in the GM Research Staff's Fuels and Lubricants Department, presented a discussion of the paper "The Exhaust Content of Automobiles Burning Ethanol-Gasoline Mixtures."

Again, on October 4, Mr. Nebel completed another speaking engagement. He discussed "Motor Vehicle Exhaust Composition and Control" before the New England Section of the S.A.E., meeting in Boston.

R. R. Bockemuehl, research engineer in the GM Research Staff's Physics Instrumentation Department, participated in the National Electronics Conference held in Chicago, October 3 to 5, by presenting the paper "An Instrument for Recording the Cylinder Pressure Versus the Crank Angle of an Internal Combustion Engine."

At the October 6 S.A.E. meeting held in New York City, **John M. Campbell**, technical director of the GM Research Staff, presented a paper on "The Big Dividend from Research in the Greatest Power Industry in the World."

Carl L. Goodzeit, research engineer in the Mechanical Development Department of the GM Research Staff, presented a discussion of the paper "Thermal Aspects of Galling of Dry Metallic Surfaces in Sliding Contact" at the 2nd Annual American Society of Mechanical Engineers and American Society of Lubrication Engineers Lubrication Conference, held in Indianapolis on October 12.

Determine the Angular Position of Two Punched Holes to Statically Balance a Speedometer Speed Cup

A speedometer speed cup, used to actuate the pointer which indicates the speed of a vehicle, must be statically balanced to obtain a straight-line calibration of vehicle speed versus pointer deflection and to reduce pointer oscillation due to car bounce. The static balancing operation at AC Spark Plug Division is based on removing the cup's out-of-balance weight by three punched holes. The position of the first punched hole is established. The angular position of the remaining two holes, however, varies from cup to cup and is a function of the angle through which the cup rotates after the first hole has been punched. This is the solution to the problem presented in the November-December 1955 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

THE static balance of the speedometer speed cup is achieved by punching three holes in the cup's outer rim. When the cup is first placed in the supporting unit of the balancing machine, the pivot-mounted oscillating roller bearings cause the heavy side of the cup W to rotate downward and rest at the bottom (Fig. 1a). The weight W represents the out-of-balance weight of the cup located at radius R . One hole is then punched on the horizontal centerline of the cup and at right angles to the heavy side. This punched hole removes a weight W_1 from the cup which is equivalent to adding an equal amount of weight W_2 on the opposite side of the cup (Fig. 1b).

After the first hole has been punched, the cup rotates through an angle α and

a new heavy side W_3 rests at the bottom (Fig. 1c). The weight W_3 represents the new unbalanced weight of the cup which must be balanced by punching the remaining two holes. Referring to Fig. 1c, an expression for W_3 in terms of the weight W_2 and the angles α and β of cup rotation can be determined as follows. Let W represent the original unbalanced weight of the cup and reduce the unbalanced weights W_2 and W_3 to the common radius R . Taking moments about the cup's center O and resolving them along the horizontal centerline, the following expression for W can be developed:

$$\begin{aligned} W_2 R \cos \alpha &= W R \sin \alpha \\ W_2 \cos \alpha &= W \sin \alpha \\ W &= W_2 (\cos \alpha / \sin \alpha). \end{aligned}$$

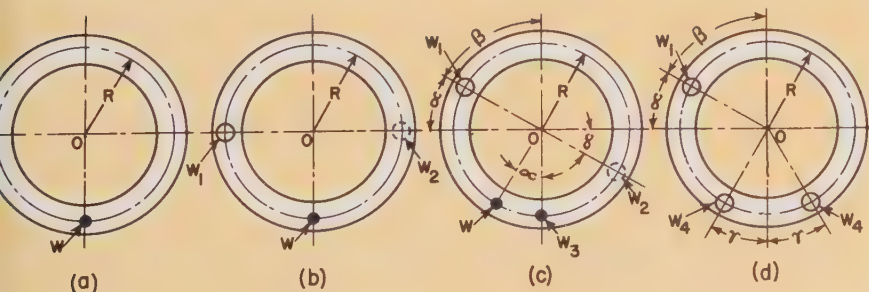
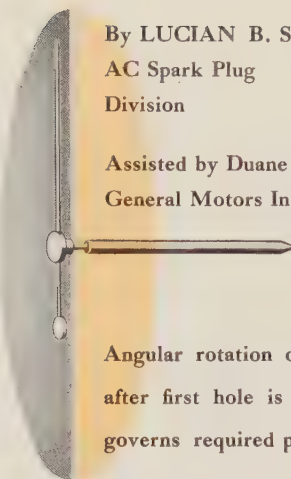


Fig. 1—When the speed cup and spindle are placed on oscillating bearings, the heavy side of the cup W rotates downward and rests at the bottom (a). One hole is then punched on the horizontal centerline and at right angles to the cup's heavy side. The punched hole removes a weight W_1 from the cup which is equivalent to adding an equal amount of weight W_2 on the opposite side (b). After the first hole is punched, the cup rotates through an angle α and a new heavy side of the cup W_3 rests at the bottom (c). This weight W_3 is balanced by punching two holes, each of which removes a weight W_4 at the variable angle γ (d).



By LUCIAN B. SMITH
AC Spark Plug
Division

Assisted by Duane D. McKeachie
General Motors Institute

Angular rotation of the cup
after first hole is punched
governs required position

By taking moments about the center O along the vertical centerline, the following expression for W_3 can be developed:

$$W_3 = W \cos \alpha + W_2 \sin \alpha.$$

Substituting in the above equation the previously determined value for W gives

$$W_3 = W_2 [(\cos^2 \alpha + \sin^2 \alpha) / \sin \alpha].$$

From the trigonometric identity that $\cos^2 \alpha + \sin^2 \alpha = 1$, the above equation can be simplified to

$$W_3 = W_2 (1 / \sin \alpha).$$

Referring to Fig. 1c, it can be seen that the $\sin \alpha$ equals the $\cos \beta$. Therefore,

$$W_3 = W_2 / \sin \alpha = W_2 / \cos \beta.$$

Fig. 1d shows the position of the remaining two holes which must be punched at an angle γ on each side of the unbalanced weight W_3 of the cup. Each of the punched holes removes a weight W_4 from the cup. The angle γ can be determined as follows. Taking moments about the center O along the vertical centerline gives

$$W_3 = 2 W_4 \cos \gamma.$$

Substituting in the above equation the previously determined value for W_3 and utilizing the fact that W_2 equals W_4 gives

$$\begin{aligned} W_2 / \cos \beta &= 2 W_2 \cos \gamma \\ \cos \gamma &= 1 / 2 \cos \beta. \end{aligned}$$

The actual punching operation entails the use of a specially designed balancing machine which contains an indicating pointer. This indicating pointer, when moved through the angle β and lined up with the first punched hole, automatically positions the two punches at the variable angle γ . This arrangement eliminates all necessity for calculating the angle γ for each speed cup which must be statically balanced.

Determine the Stiffness of a Fabricated Steel Supporting Structure for a Diesel Engine

By ROBERT F. ZALOKAR
Cleveland Diesel Engine Division

Assisted by William H. Lichty
General Motors Institute

Inherent exciting forces in a Diesel engine, resulting from the unbalance of reciprocating and rotating component parts, can cause severe vibrational problems if the engine is not supported properly. To avoid resonance with periodic unbalanced forces within the engine it is necessary to determine the natural frequency of the complete engine-support installation. This can be done by considering the engine and its support as a system of masses and elastic members and by calculating the actual value of these masses and elastic members. The engineer, when comparing the natural frequency of the engine-support installation with the known unbalance frequency of the engine, can then take steps to change the stiffness of the most flexible member of the support in order to avoid a resonant condition.

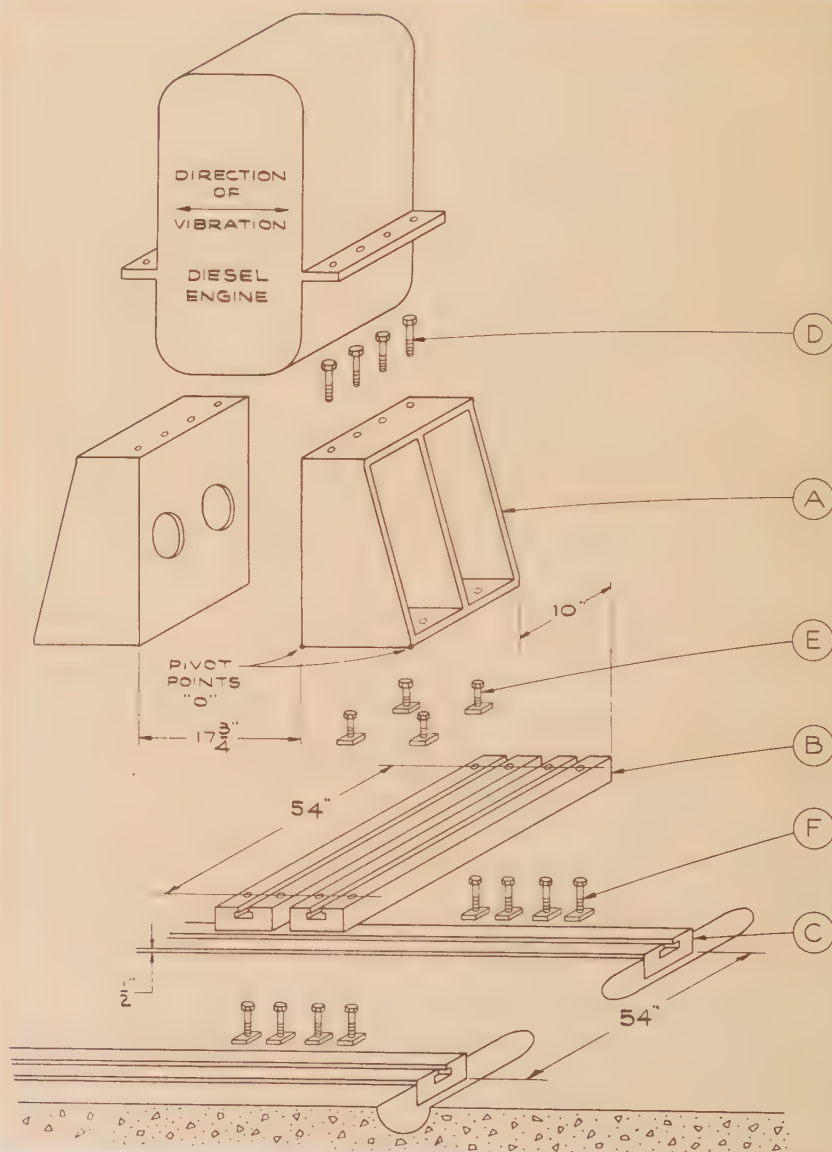
IN the design of Diesel engine installations, it frequently becomes necessary to determine the natural frequency of the installation in order to prevent resonance with exciting forces inherent in the engine. Usually, the engine supporting structure is sufficiently rigid so that only the fundamental frequency caused by engine unbalance is near resonance in the operating range. It is important nevertheless to keep vibration at a minimum in order to maintain customer satisfaction and to prevent the possibility of costly repairs to the equipment.

The two important steps for a vibration analysis are:

- (a) The breakdown of the structure into equivalent masses and elastic members which will most realistically represent the physical arrangement of the system and which will result in an accurate elastic curve.

Fig. 1 (Right)—The Diesel engine and its supporting structure is a complex combination of masses and elastic members which forms the basic structural requirements of a vibration system. The application of a periodic exciting force, produced by the unbalance of moving parts within the engine, can cause motion of the vibration system. In order that resonance with periodic unbalanced forces within the engine will be avoided the design engineer must determine the natural frequency of the complete engine installation. Before this can be accomplished, however, it is necessary to calculate first the stiffness of the supporting structure which consists of two similar test bases *A*, test-base rails *B*, foundation rails *C*, and hold-down bolts *D*, *E*, and *F*.

Stiffness of base must be determined to avoid resonance with engine excited forces



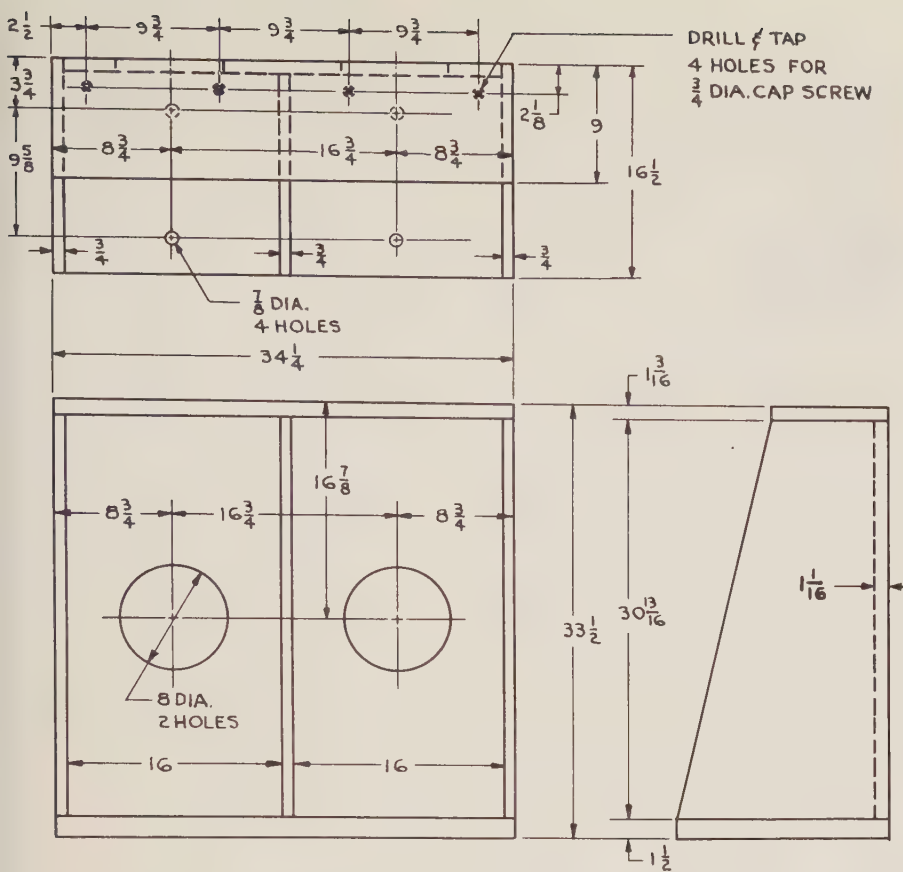


Fig. 2—The test base member of the engine's supporting structure has a horizontal exciting force of 5,000 lb applied along its top. This force causes a certain amount of deflection which can be determined by using the second area-moment proposition.

- (b) The calculation of the equivalent masses and elastic members.

After an engineer has calculated the actual values of the equivalent masses and elastic members, he can determine the natural frequency of the system by an appropriate formula and compare it to the frequency of the known unbalanced forces. If this comparison indicates that resonance will occur within the speed range of the engine, the engineer then can take steps to shift the natural frequency to a more desirable location.

The most interesting part of a vibration analysis is outlined in step (a) where the basis for all the engineer's calculations is established. The engineer should attempt to obtain a simplified equivalent mass-elastic system that will most realistically represent the actual structure to be analyzed. Assuming that a satisfactory mass-elastic system has been determined, the accuracy of the final answer then will depend on the engineer's ability to evaluate the elastic action of the flexible members of the system.

In order to illustrate the use of steps (a) and (b), a simple but actual problem involving a fabricated steel support base for testing Diesel engines is presented.

Problem

Fig. 1 shows an exploded view of a typical Diesel engine test-stand installation used by the Cleveland Diesel Engine Division. The supporting structure is composed of two individual sections, each of which contains one test base *A*, two steel test-base rails *B*, two foundation rails *C* which are similar to the test-base rails and which protrude $\frac{1}{2}$ in. above the concrete floor, and hold-down bolts *D*, *E*, and *F*. Bolts *E* and *F* are $\frac{7}{8}$ in. and 1 in. in diameter, respectively.

Fig. 2 shows a detail drawing of the test base *A*. Fig. 3 shows a cross sectional view of a test-base rail.

The problem is to determine the equivalent mass-elastic system of the structure shown in Fig. 1 and to calculate the overall equivalent stiffness of one section of the engine support mem-

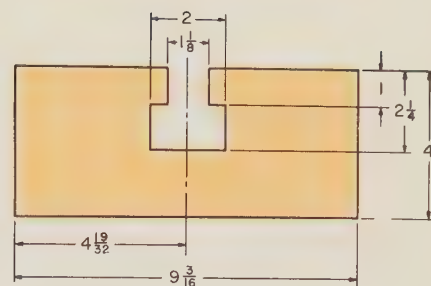


Fig. 3—The test-base rails and foundation rails used in the supporting structure are similar in design.

bers, assuming that a horizontal exciting force of 5,000 lb is distributed evenly along the top of the test base.

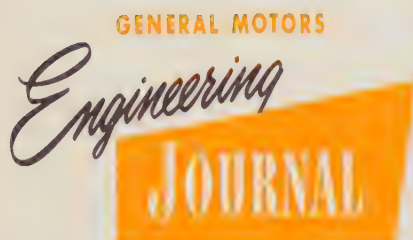
Assume a one mass system where the weight *W* represents the weight of the engine and part of the weight of the two test bases. The weight added by the two test bases depends on their stiffness as compared to the stiffness of the other elastic members. This equivalent weight, in turn, is supported dynamically in the horizontal direction by two sets of springs. Each set is composed of three springs and represents one section of the supporting structure.

To obtain the overall equivalent stiffness of one side of the supporting structure, it is necessary to calculate the individual stiffness values for the test base *A*, test-base rails *B*, and the test base hold-down bolts *E* and then combine these values. Assume that the test base is a cantilever beam fixed at the bottom surface and having a variable moment of inertia *I*. The deflection Δ of the top of the test base resulting from the horizontal exciting force may be found by the second area-moment proposition. Also assume that the test-base rails act as simply supported beams and that the test base hold-down bolts are in tension when the test base rocks on pivot points 0 (Fig. 1).

As the problem is analyzed, it will be interesting to observe which part of the structure is the most flexible, and suggestions should be given on how to increase the stiffness of this member.

The results of an actual static load deflection test, performed on one section of the supporting structure to validate the analytical calculations, will be presented with the solution to the problem which will appear in the March-April 1956 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Contributors to Jan.-Feb. 1956 Issue of



**ALFRED
CANDELISE,**

contributor of "An Improved Method for the Economic Reconditioning of Aircraft Spark Plugs," is staff engineer in charge of spark plug design and development work at AC Spark Plug Division, Flint, Michigan.

Mr. Candelise originally joined AC Spark Plug in 1934 as a research engineer in the Dynamometer Laboratory. In 1940 he was promoted to the position of project engineer and was engaged in spark plug development work. Four years later he became a senior project engineer and in 1952 was promoted to executive engineer for spark plug design and development work. He assumed his present position in 1955.

A native of Italy, Mr. Candelise was graduated from the University of Naples in 1923 with the Ph.D. degree in electrochemical engineering. He came to the United States the following year and was employed from that time until 1933 by the Ford Motor Company.

Mr. Candelise's work has resulted in the granting of several patents in the field of spark plug design. He has had several papers published relating to the fields of engine combustion study and combustion chamber design. His technical affiliations include membership in the Society of Automotive Engineers.

**HARRY J.
GILLILAND,**



co-contributor of "Causes and Control of Distortion during Machining of Aluminum-Alloy Forgings," is a senior metallurgical engineer in the Process Development Section of the General Motors

Manufacturing Staff, whose facilities are located at the General Motors Technical Center.

Before transferring to the Process Development Section in May 1955, Mr. Gilliland was general supervisor of Manufacturing and Development at the Kansas City plant of Buick-Oldsmobile-Pontiac Assembly Division. He joined B.O.P. in May 1951 as a metallurgical engineer in the Laboratory and Development Department. In September of the same year, he was promoted to supervisor of Metallurgical Development and in February 1954 was appointed general supervisor of Manufacturing and Development.

Some of Mr. Gilliland's responsibilities at B.O.P. included setting up all the heat treatment facilities for the F-84F Thunderstreak production program (discussed in his paper), establishing procedures for cold forming and straightening operations, and overseeing work done with plastics, fusion and resistance welding, finishing, mechanical fastening, and metallurgical operations. At the Process Development Section he is concerned with metallurgical processing and development.

Mr. Gilliland received the B.S. degree in metallurgical engineering in 1947 from the Missouri School of Mines and Metallurgy, Rolla, Missouri. He is a member of the American Society for Metals and the National Society of Professional Engineers.

**HAROLD E.
HELMS,**



contributor of "Applying Engineering Mechanics: Find the External Support Reactions of an Allison Turbo-Prop Engine," is a senior project engineer in the Advance Design and Develop-

ment Department of Allison Division, Indianapolis. Mr. Helms' paper represents one of the typical problems encountered in his current major projects of designing and testing structural and operating parts of Allison turbo-prop and turbo-jet engines.

Mr. Helms originally joined General Motors in 1943 as a junior detailer in the Engineering Department of Chevrolet Motor Division's assembly plant at Muncie, Indiana. He left this Division to enter Purdue University which granted him the B.S. degree in engineering mechanics in 1948 and the M.S. degree in the same field in 1950. While studying for his master's degree Mr. Helms served as an instructor in civil engineering and engineering mechanics.

After receiving his master's degree Mr. Helms joined the Argonne National Laboratories, Lemont, Illinois, where he did developmental work on the reactor component of the nuclear-powered submarine. He left this concern in May 1952 to join Allison Division as a project engineer in the Power Turbine Engineering Department. In this capacity he was concerned with doing design and test work on structural components of the turbo-prop engines used as the power plants for the VTO (vertical take-off), the R3Y Tradewind and other aircraft. He was promoted to senior project engineer in June 1953. In April 1955 he was transferred into the newly created Advance Design and Development Department where he is currently doing design and testing on structural and operating components of advanced models of turbo-prop and turbo-jet engines.

Mr. Helms is a member of the Chi Epsilon civil engineering honorary engineering society and Sigma Xi. He also is a member of the Society for Experimental Stress Analysis, the Institute of the Aeronautical Sciences, and is a registered professional engineer in the State of Indiana.

**CLIFFORD W.
HOCKMAN,**



contributor of "Progressive Mechanization as Applied to Core Making in a Production Foundry," is superintendent of Cadillac Motor Car Division's foundry, located at the Detroit, Michigan, plant.

Mr. Hockman has been actively connected with varied phases of foundry work since 1916 when he started in a foundry in Williamsport, Pennsylvania. In all, he has worked for 10 different foundries in six states in the past 40 years, foundries producing castings of all types—machine tool, automotive, and aircraft.

Some of the highlights of his industrial career include pioneer work in the use of dense coke for greater capacity production, participation in developing the Roxey method for boring injection, development of the Zirconite Process for patterns and core boxes, research on use of ferro-carbo material for improved castings, and perfection of a facing sand for better finishes.

During World War II he managed three foundries—magnesium, iron, and aluminum—as an executive account engineer for Associated Engineers, Incorporated, Fort Wayne, Indiana. Other war work included conversion of two iron foundries for the production of magnesium castings for aircraft.

Mr. Hockman joined Cadillac Motor Car in March 1949 as executive assistant superintendent of the foundry and was promoted to superintendent in February 1950.

Mr. Hockman is active in technical society work. He is chairman of the Detroit Chapter of the American Foundrymen's Society and is a member of the Society's Sand Committee. In addition, he is a board member of the Michigan Foundry Educational Foundation and is chairman of the General Motors Foundry Committee.

CHARLES E. KINCAID,



contributor of "Investigation of Barrel Finishing as a Means of Efficient Burr Removal," is a senior process engineer in the Master Mechanics Division of Allison Division, Indianapolis, Indiana.

In August 1941 Mr. Kincaid joined Allison as a clerk in the Aircraft Engine Test Department, enrolling as a co-operative student at General Motors Institute in September 1942. Mr. Kincaid's studies were interrupted by active duty in the Army and Air Force from June 1943 until February 1946. He re-

entered G.M.I. in March 1946 and was graduated in August 1949. Upon completion of the Thesis Program at G.M.I., Mr. Kincaid was granted the B.I.E. degree in 1954. (Mr. Kincaid's paper in this issue is his adaptation of the thesis he submitted to fulfill the requirements for the B.I.E. degree.)

In November 1949 Mr. Kincaid was made a production foreman and in January 1954 he was promoted to process engineer with the responsibility of correlating the processing and production of gears. In addition, he assisted in the development and purchase of tooling for gear production and made recommendations and changes to facilitate production and to improve the quality of gear parts.

In November of the same year he transferred to the Purchasing Department as a tool buyer and was responsible for purchasing all gear tooling such as broach bars, hobs, shaper cutters, and shaving cutters. His latest promotion, senior process engineer, took place in November 1955. He supervises the activities of those process engineers engaged in gear work for the Division.

THOMAS O. MATHUES,



sion, Dayton, Ohio.

Mr. Mathues joined Inland Manufacturing in 1940 as an engineering student in the Personnel Department and en-

contributor of "A Discussion of Major Factors Affecting the Fabrication of Rubber Parts by Extrusion," is director of laboratories in the Engineering Department of Inland Manufacturing Divi-

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rolled at General Motors Institute as a co-operative student. World War II interrupted Mr. Mathues' schooling from 1944 to 1946 during which time he served in the United States Navy as an electronics technician and also as an instructor of advanced electronics. After separation from the service, he returned to G.M.I. and Inland Manufacturing where he assumed the position of physical testing engineer. In 1947, he received the B.M.E. degree from G.M.I. One year after his graduation, he was promoted to project engineer for the Latex Pilot Plant. In 1950 he became supervisor of the physical testing laboratory and in 1952 assumed his present position.

At the present, Mr. Mathues directs all activities of nine engineering laboratories. His past projects were development of wet-mixed rubber compounds for weatherstrips and steering wheels, foam rubber products, and development of dynamic test methods and equipment to determine the dynamic properties of rubber.

Three patents in the fields of rubber technology and electrical instrumentation have resulted from Mr. Mathues' work. His technical affiliations include the American Society for Testing Materials—Committee D-11 (Rubber), past chairman of Dayton Section of the Society of Automotive Engineers, and is a member of the S.A.E. National Committee on Laboratory Testing of Brake Lining.

LUCIAN B. SMITH,



who prepared the problem "Determine the Angular Position of Two Punched Holes to Statically Balance a Speedometer Speed Cup" and the solution appearing in this issue, is chief test engineer in

the Automotive Test Laboratory of AC Spark Plug Division, Flint. In this capacity, Mr. Smith supervises tests of all automotive products submitted to the Automotive Test Laboratory.

Mr. Smith joined AC Spark Plug in 1923 as a test laboratory assistant shortly after receiving the B.E.E. degree from The Ohio State University. Four years later he was promoted to assistant head of the Test Laboratory and in 1930 he became a test engineer. During World

War II he served as test engineer on military products, in charge of test equipment procurement for a number of Air Force projects relating principally to gun sights and bomb sights. In 1947 he was promoted to his present position.

Mr. Smith's work in the testing laboratories has resulted in 10 granted patents.

He is a member of Eta Kappa Nu, honorary electrical engineering fraternity, and Pi Mu Epsilon, honorary mathematics fraternity. Mr. Smith's technical society affiliations include membership in the Society of Automotive Engineers and the American Institute of Electrical Engineers.

LOYL R. THOMAS,



co-contributor of "Causes and Control of Distortion during Machining of Aluminum-Alloy Forgings," serves Buick-Oldsmobile-Pontiac Assembly Division as a staff assistant in its Central Office Quality

Standards Department, located in Detroit. He transferred to the Central Office from B.O.P.'s Kansas City plant in February 1955. As staff assistant, Mr. Thomas' current responsibility is the establishment and the coordination of a statistical quality control program at seven of B.O.P. Assembly's plants; these programs are aimed at producing higher quality, more economically built automobiles through organizing assembly operations for quality construction.

After receiving the B.S.M.E. degree in 1948 from the South Dakota State College, Mr. Thomas stayed on for a year at the College as an instructor in mechanical engineering. From 1949 until 1951, while doing graduate work in this same field at the University of Kansas, he taught mechanical engineering to University undergraduates.

In August of 1951 Mr. Thomas joined B.O.P.'s Kansas City plant as a mechanical engineer in the Laboratory and Development Department. From February 1952 until February 1955 he was intimately connected, in various capacities, with the problems attendant to the production of the F-84F Thunderstreak fighter-bomber. One particular problem, the prevention of distortion during the machining of aluminum-alloy spars, Mr.

Thomas discusses in his paper presented in this issue.

Mr. Thomas' technical affiliations include membership in the American Society of Mechanical Engineers, the American Society for Metals, and the American Society for Quality Control.

STANLEY C. THORPE,



contributor of "Notes About Inventions and Inventors," is a patent attorney supervisor in the Central Office of the General Motors Patent Section, located in Detroit. The Patent Section's other two

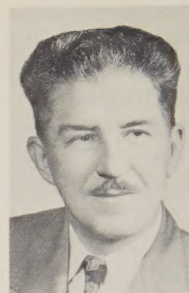
offices are at Dayton, Ohio, and at Washington, D. C.

As a patent attorney, Mr. Thorpe's duties include patent matters involving the preparation of patent applications for inventions developed by General Motors personnel, the investigation of infringement and validity considerations on new or changed devices and for processes now used in production, and the development of license agreements pertinent to devices used in production. In his role as patent attorney supervisor he is concerned mainly with those patent matters affecting the Detroit Diesel Engine, Cleveland Diesel Engine, Diesel Equipment, Electro-Motive, and Saginaw Steering Gear Divisions.

In 1937, directly after earning the B.S. degree in mechanical engineering from the Michigan College of Mining and Technology, Mr. Thorpe joined General Motors as a laboratory technician in the Experimental Engineering Department of Chevrolet Motor Division at Detroit, Michigan. In 1942 he was shifted to the Chevrolet Aviation Engine Division at Tonawanda, New York, as supervisor of test reports, and also during that year he received the LL.B. degree from Wayne University, Detroit. He transferred in 1945 to the Washington, D. C. office of the Patent Section as a searcher. In September 1947 he was made a patent attorney in the Detroit office of the Patent Section and was promoted to his present position, patent attorney supervisor, in May 1953.

Mr. Thorpe is a member of the State Bar of Michigan and of the Michigan Patent Law Association.

DANIEL C. WILKERSON,



contributor of "GM Colorline Process Simplifies Making of Color Slides," is an engineer in the Transmission Development Section of the General Motors Engineering Staff, Detroit. Mr. Wilkerson's career

since attending Maryland State College and the U.S. Naval Academy has been characterized by variety. Before joining General Motors in 1925 as an overseas engineer, he served as automobile and science editor of the Washington Herald, as an automotive instructor for both the Y.M.C.A. Motor School, Washington, D.C., and for the U.S. Army Engineer Corps, and as an electronic consultant and contributor to publications dealing with electronic developments.

Mr. Wilkerson's past assignments with General Motors include preparation of many GM patents on automatic transmissions, preparation of the GM Management Manual on Overseas Factory Showrooms, and installation work for overseas factory electroplating shops. His current work involves organization of historical background data on the evolution of GM transmissions which led to his interest in the development of the Colorline process, outlined in his paper in this issue.

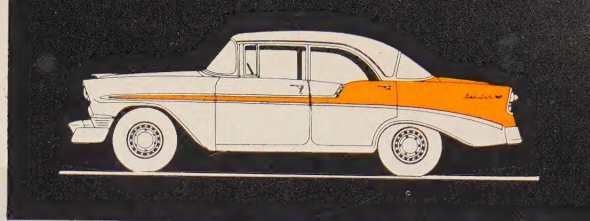
He is a member of the Michigan Patent Bar Association, serving as chairman of the Committee for Co-operation with the U. S. Patent Office. For the Engineering Society of Detroit Mr. Wilkerson serves on the Program Committee. He is also a trustee of the U.S. Naval Academy Alumni Association.

Mr. Wilkerson's work has led to three granted patents in the fields of electronics, automatic drive and control mechanisms, and electroplating.

Reprints Available

Reprints of the paper entitled "How to Organize and Write Effective Technical Reports" by Ralph A. Richardson and C. A. Brown—GM ENGINEERING JOURNAL, September-October 1955—are available free to educators on request to:

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FASHION FOR FIFTY-SIX

Long before Chevrolet's fresh style for fifty-six was announced to the general public, stylists in GM's studios were hard at work on the '56 design. The photograph above shows a section of the ultra-modern studio at the new General Motors Technical Center where Chevrolet's passenger car styles are conceived and developed. Freehand sketches such as the ones shown in the foreground are the initial

step toward a new design. Full-scale working drawings come next. From the drawings a clay model, shown in the background, is molded by skilled craftsmen over a rough wood frame called a "buck". The clay model serves as a three-dimensional pattern for making templates and molds used to fashion the plastic and metal prototype shown at the right. Production drawings are made from this prototype.

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